THE FOSSIL CRINOID GENUS DOLATOCRINUS AND ITS ALLIES.

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CRINOID FAUNAS OF THE MIDDLE DEVONIAN.

The crinoids which form the subject of this Bulletin constitute a small group of generic forms having a singularly restricted distribution, being confined, so far as known (after a feeble beginning with two hitherto undescribed species in the Niagaran and Helderbergian),[1] to the Middle Devonian of North America. They belong typically to the Gulf fauna, which during Onondaga time brought widespread coral reefs into the interior region—best developed in the Louisville, Kentucky, area. The faunas introduced by this Gulf invasion continued through the later Onondaga and Hamilton epochs, persisting in the Louisville area, extending far to the north into Canada, and migrating around the Cincinnati axis into the western part of New York.

This is the interpretation of the faunal conditions of that time given by Prof. Charles Schuchert, in his Paleogeography of North America,[2] based upon general paleontological evidence; and the occurrence of the crinoid forms under consideration is in perfect agreement with it. The principal colony was in the Louisville area, where these forms appear in rocks of Onondaga age, culminating and becoming extinct in the succeeding Hamilton. They spread northward and northeasterly, into Michigan, western New York, and adjacent Canadian localities. No representative of these genera is known outside of the limits thus indicated.

The leading type in abundance, so far as our collections show, was *Dolatocrinus*, which from a few well-marked species in the Onondaga increased to great profusion in number and variety, reaching its acme in the Hamilton, where it is represented by numerous species. But whereas in the Onondaga the species were extremely well defined, rapid development ensued in the Hamilton under conditions favorable to a rampant growth, in which certain characters, stable and thoroughly reliable in the earlier formation, become worthless for

[1] Springer. On the crinoid genus *Scyphocrinus*, 1917, p. 25.

[2] Bull. Geol. Soc. Amer., vol. 20 (1910), pp. 540, 544-545.

the discrimination of species. This was followed by complete extinction, no vestige of this or allied types having ever been found in later formations.

The forms in question are all included in the suborder Camerata, but for lack of material the treatment of them in the monograph of that group by Wachsmuth and myself in 1897[3] was inadequate. A considerable number of new species has been since described by other authors, and I have in the meantime accumulated much additional material. This in conjunction with the types of the later described species—chiefly in the Walker Museum of the University of Chicago, generously placed at my disposal by Doctor Weller—will afford the information necessary for a more satisfactory discussion and illustration of these genera. Many drawings for this purpose were prepared some years ago, but the further preparation and publication of the memoir have been delayed by the pressure of other work.

The occasion for the present paper is the desirability of making available for the use of others some of the matter which I have long had in manuscript bearing upon the generic relations of the several forms comprising this group, including the recognition of two new genera.

The group belongs to the Camerate family Melocrinidae, which was for convenience divided by Wachsmuth and Springer[4] into two sections, Melocrinites and Dolatocrinites, based upon characters not sufficiently constant for family distinction. By transferring the genus *Patelliocrinus* to the first of these sections and placing it next to *Macrostylocrinus* with three basals, we shall have the two sections somewhat better defined with reference to the general habitus and form of calyx than they have been when depending upon the very slight and indecisive difference in the plates of the anal interradius above the first range. The genera of the first section all have a more or less elongate calyx, the dorsal cup being usually higher than wide, subturbinate in form, expanding from a relatively narrow base to the zone of greatest width at the level of the arms. In the second section these characters are more or less reversed, the cup being usually subovoid or hemispheric, broadly rounded, and wider than high. *Technocrinus* may be regarded as an intermediate form, the earlier species, now herein described, being of the latter type.

The new genera are proposed for forms, one of which was described by Miller and Gurley as *Stereocrinus indianensis*, and the other by Lyon as *Hadrocrinus plenissimus*, and both of which are

[3] North American Crinoidea Camerata, Memoirs Museum Comparative Zoology, Harvard, vol. 21, pp. 304–329.

[4] North American Crinoidea Camerata, pp. 264–267.

thoroughly distinct from the types with which they have been associated. The following definition and brief discussion will be sufficient for the present purpose:

Family MELOCRINIDAE; section Dolatocrinites.

Monocyclic. Lower brachials, with well-defined interbrachials, forming part of the dorsal cup. Radials in contact all around. Symmetry of dorsal cup but little, or not at all, disturbed by anal structures; cup usually wider than high, broadly rounded below, with base depressed, flattened, or concave. Arms usually simple; biserial with few exceptions.

ANALYSIS OF THE GENERA.

Basals 4:
- Arms simple, biserial; base obconical; no anals. ..... Technocrinus.
- Arms branching, biserial both above and below the bifurcations; base forming an inverted cone; no anals. ..... Clonocrinus.

Basals 3, unequal, sometimes anchylosed:
- Calyx usually small, or of moderate to large size; iBr few, in not over two ranges.
  - Anal side not differentiated in dorsal cup.
    - Dorsal cup low and wide; basals small, undivided, sunk in a shallow cavity; arms simple, uniserial..... Allocrinus.
    - Dorsal cup higher than tegmen, broadly rounded; base usually flattened or concave.
      - Tegmen flat or low convex, nearly symmetrical, with subcentral anal tube.
        - Arms little known; probably biserial, and simple, except in one species which should go into another genus; openings 10 to 40.
          - Basals small; usually in a conical depression and anchylosed; the smaller one, when distinguishable, in left anterior position.
            - IBr 2..... Dolatocrinus.
            - IBr 1..... Stereocrinus.
  - Anal side slightly differentiated in the dorsal cup by an extra plate in second range.
    - Dorsal cup subcylindrical; basals large, divided; radials large, IBr small; arms unknown ..... Centriocrinus.
  - Anal side also strongly differentiated in the tegmen by a series of large, ridge-like plates extending from the second iBr range to base of anal tube.
    - Dorsal cup low, broadly rounded, base flattened or concave; basals usually divided.
      - Tegmen exceeding dorsal cup in height, strongly bulging posteriorly, but with subcentral anal tube.
        - Arms uniserial, simple.
          - Basals distinct; small basal in left posterior position; IBr 2, the first reduced and irregular in form..... Comanthocrinus, new genus.

Basals 3, unequal, sometimes anchylosed—Continued.
Calyx very large; iBr in 3 to 7 ranges.
Anal side may be slightly differentiated above the first range.
Dorsal cup broad, low, and flattened.
Tegmen low convex.
Base small, with shallow concavity involving radials and covered by column; basals almost eliminated by atrophy.
Arms biserial, simple, heavy and few in number—about 4 to the ray; iBr in 5 or more ranges.
IBr 1..... HADROCRINUS.
Dorsal cup broadly rounded.
Base deeply concave, forming an inverted cone.
Arms biserial, simple, small and numerous—16 or 17 to the ray; iBr in not exceeding 3 ranges; IBr 2, the second reduced and irregular in form..... HIMEROCRINUS, new genus.

The material used in the following descriptions and discussions and in the illustrations, unless otherwise stated, is all in the author's collection now in the United States National Museum.

COMANTHOCRINUS, new genus.

In addition to the larger characters for this genus previously mentioned, the following observations are pertinent:

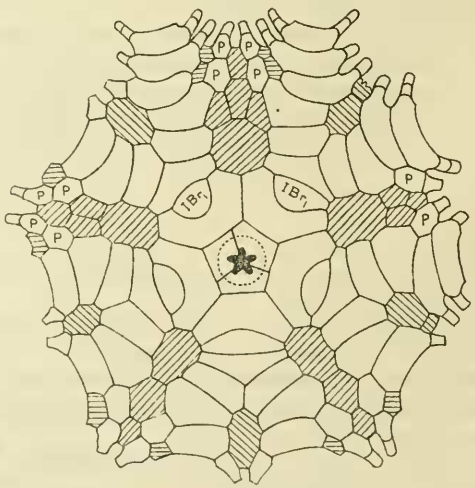

FIG. 1.—COMANTHOCRINUS.

//// = i Br \\\\ = i II Br
= = = interpinnulars p = pinnulars

The greatly elevated tegmen, with its conspicuous bulging at the posterior side, and the accompanying marked differentiation of the anal series, produce a wide departure from the nearly pentamerous symmetry which prevails in most of the genera of this group. The

bulging is due to the great enlargement and asymmetrical swelling of the intestine, which nevertheless discharges from the tegmen almost centrally, through a small anal tube. The interbrachials are few in number, consisting of one large plate, which may be followed by one or two in the succeeding ranges, flanked by other plates resembling interbrachials, but which are in fact fixed pinnulars; interpinnulars sometimes present. The anal side is differentiated in the tegmen by a median row of large plates, and sometimes in the dorsal cup by an extra plate in the second interbrachial range, but this is not constant; a narrow linear series passes up to the median row above mentioned.

The base, in the left posterior position of the small plate, is not only different from that of the associated genera, but is a departure from the rule in monocyclic crinoids generally, this exceptional orientation being known only in some specimens of *Storthingocrinus*, and the Recent genus, *Hyocrinus*. This character is nearly constant in both species.

The condition of the first primibrach is also exceptional and peculiar. Instead of being absent, as in *Stereocrinus* and *Hadrocrinus*, it is reduced to a small lunate or elliptic plate, occupying a curved socket cut out of the distal face of the radial (or also out of the plate above it), usually less than the width of that plate, but sometimes extending entirely across it. A similar irregularity has been observed in *Eucalyptocrinus rosaceus*, from the Devonian of the Eifel, in which the first primibrach is also sometimes entirely absent.

The secundibrachs are arched into strongly rounded rays, with broad depressions between. They form a continuous series which pass into 10 strong, free, uniserial arms. They are incorporated in the calyx to a varying extent by means of fixed pinnules, the bases of which are closely united by suture. The lower secundibrachs following the first bear a single pinnule, on the outside and inside of the dichotom successively, while $IIBr_4$, and probably all succeeding brachials bear pinnules on both sides, increasing in number until there are two on each side. This bipinnulate or quadripinnulate structure is also unusual, but I have other good examples of it in the genera *Carpocrinus* and *Lampterocrinus*. Ambulacral covering plates in double series extend to near the base of the anal tube, and pinnular ambulacra are also present, as in *Marsipocrinus*. These pinnules give rise to openings through the calyx wall between the bases of the rays, such as have been noted in species of *Dolatocrinus*, *Batocrinus*, and other genera, in which they were formerly interpreted as "respiratory pores." I have already explained their nature and origin in the memoir on the genus *Scyphocrinus*, 1917, (pp. 40–46).

In the great preponderance of the ventral portion of the calyx, as evidenced by the flattened dorsal cup and high tegmen, this genus

resembles the condition of the adult comatulids generally, in which the base is only a platform for the support of the visceral mass, in contrast to the typical plan of the crinoids, in which the dorsal parts form a cup inclosing the viscera. Among the paleozoic crinoids of other Camerate families some exceptionally took the same form, as, for example, the genera *Agaricocrinus*, *Amphoracrinus*, *Cyphocrinus*, and the discoid species of *Platycrinus*.

The genus is represented by at least two species, one from the Onondaga and one from the Hamilton. The Hamilton form was described by Miller and Gurley as *Stereocrinus indianensis*,[5] with little indication of its peculiar characters, although they noted that the species bears little or no resemblance to the type, and referred it to *Stereocrinus* only because of its supposed identity under the generic formula of "two primary radials"—that is, only one primibrach. Even this was incorrect observation, the authors failing to see the reduced first primibrach, which is constant in all specimens in which the plates can be distinguished. Their type was from the Louisville area, where a number of specimens preserving the tegmen have been found. Specimens of what may be the same species occur in the Hamilton of western New York, in one of which the character of the uniserial arms is well shown.

The Onondaga species is much larger. Specimens from the Falls of the Ohio at Louisville show some structural details better than the Hamilton form, especially the extreme of fixed pinnulation; but the tegmen is not preserved. Therefore I take the *S. indianensis* as the type of the genus, and for the Onondaga form I propose the name *Comanthocrinus priscus*. The latter species also occurs in western New York.

Genotype.—*Stereocrinus indianensis* Miller and Gurley.

Distribution.—Middle Devonian: Louisville area and New York.

COMANTHOCRINUS INDIANENSIS (Miller and Gurley).

Plate 1, figs. 1–6.

Stereocrinus indianensis Miller and Gurley, Bulletin No. 12, Illinois State Museum, 1897, p. 38, pl. 3, figs. 13–15.—Rowley in Greene, Contr. Ind. Pal., 1904, vol. 1, p. 182, pl. 54, figs. 7, 8.

Type of the genus. The species is of relatively small size, average specimens being about 20 mm. wide on the base and 17 mm. high to the top of the tegmen. Dorsal cup low and flat; the relations of its component plates are best shown by the accompanying generic diagram (text fig. 1), composed upon the evidence of 12 specimens of this species; the reduced and modified first primibrach is drawn in its various forms in the different rays, also variations in the inter-

[5] Bull. No. 12, Ill. St. Mus., 1897, p. 38, pl. 3, figs 13-15.

brachials. The species represents a retrogression from the older form in the less extent of incorporation of brachials in the calyx, or a progression in the direction of greater freedom of the arms, whichever way one pleases to consider the case. The chief resulting difference to be noted is in the number and depth of incorporation of the fixed pinnules. Here the arm becomes free at about the third or fourth IIBr. $IIBr_2$ has an incorporated pinnule on the outer side of the dichotom, the base of which may also connect by suture with $IIBr_3$ and $_4$. $IIBr_3$ has a free pinnule at the inside of the dichotom, and $IIBr_4$ bears two free pinnules, one from each side. Beyond this in the free arm the pinnules increase to three and four to the brachial. In a specimen with arms the pinnulation can be traced on the outside of the dichotom to the twenty-second free brachial, and on the inside to the seventeenth. All have at least one pinnule at each side, and about 12 brachials have two pinnules at one or both sides. On bipinnulate brachials the outer pinnule is usually at a different level from the inner. The pinnules are extremely slender, and in the one specimen in which they are partially preserved divide into still smaller branches. The openings for the fixed pinnules are small, round, and project slightly from the edge. The course of the tegmen ambulacra leading to them may be traced by the elongate slits, from which the minute covering pieces have fallen away. (Compare figs. 4 and 10 on pl. 1.)

Interbrachials in the second range usually two (or only one) in number, with an additional plate between the two at the anal side, usually followed by a single plate in the third range. The anal side is well distinguished in the tegmen by a row of large plates (the largest in the tegmen) having a well-defined median ridge extending from just above the brachial zone to the base of the anal tube; the swollen area which marks the position of the gut does not coincide with this ridge, but lies asymmetrically to the left of it. The tegmen is highly elevated, strongly bulging at the left posterior; the anal series and some of the axillary ambulacrals sharply pustulose. Interbrachial plates of dorsal cup may have obscure ornamentation, usually obliterated.

Horizon and locality.—Hamilton formation: Clark County, Indiana; Louisville, Kentucky; and Ontario County, New York.

COMANTHOCRINUS PRISCUS, new species.

Plate 1, figs. 7–10.

A species double the size of the type—an average of 8 specimens being about 40 mm. width of calyx at the arm bases. As the tegmen has not been found, the comparative height can not be given. Dorsal cup broad, shallow, and strongly concave. The disparity in size evidenced by the wider spread of calyx in this species is correlated

with a much greater extent of incorporation of brachials by means of the fixed pinnules. The broadly rounded secundibrachs are strongly arched exteriorly, and are deeply V-shaped on the ventral side, the wings of the V being further prolonged by the pinnules, the lower ossicles of which form a continuous wall in the depressed interbrachial areas. These give the appearance of numerous iBr plates above the very large first interbrachial; but in fact the interbrachials are limited to a single narrow plate following the first, or two in linear series, the second of which may not reach to the exterior, while the other rather numerous plates in the area are all pinnulars. In this way secundibrachs to the height of the seventh are incorporated. $IIBr_2$ has a pinnule to the outside of the dichotom, and $IIBr_3$ has one to the inside, neither of them showing externally (except at the margin), with 3 or more pinnule-ossicles incorporated. $IIBr_4$ to $IIBr_8$ have from 2 to 4 pinnules to each brachial, with 2 or more pinnulars incorporated. The reduced first primibrach occupies an oval space between the radial and the axillary IBr_2, both of which are more or less excavated for its reception. It is usually small, strongly protuberant, and the radial ridge following the rays begins with this plate. The anal side is scarcely differentiated, two narrow plates tandem succeeding the large first plate and passing toward the tegmen, which is not preserved in any of our specimens.

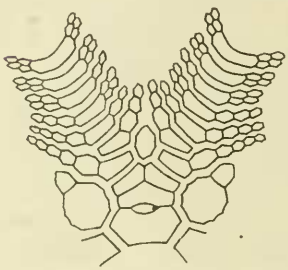

FIG. 2. PINNULES OF COMANTHOCRINUS.

The inside of the dorsal cup is marked by an extraordinary complex of grooves and ridges from the basals and radials up, which are doubtless for the lodgement of nerve cords, but the exact function of so many is not clear. They are comparable in number and position with the ridges and furrows seen upon the dorsal side of calyx plates in well-preserved specimens of *Himerocrinus plenissimus*, but nothing so intricate has been observed upon the inner surface in other forms. A few sharp nodes appear at the exterior on radials and interbrachials.

Most of the material is in poor condition, but we are fortunate in having two specimens which, except for the lack of the tegmen, are remarkably well preserved for exhibiting the essential characters of the species; in one the dorsal and ventral surfaces are completely exposed, and in the other the ventral side only. By means of these we are able to illustrate both aspects of the calyx, and to show the actual relations of the incorporated plates by diagrammatic sketch, as well as by direct drawings. Several other fragmentary specimens confirm the description in various particulars.

With the incorporation of the lower pinnules in the calyx wall by the growth of interradial structures, the space available for their accommodation became reduced, resulting in more or less displacement by crowding, packing and overlapping, so that the pinnulars can not always be traced in linear succession, especially at the dorsal side. Some pinnulars well developed at the interior of the calyx wall are smaller exteriorly, or are not seen at all, thus giving rise to confusion when comparing the different views in the figures. Thus the first pinnule, as seen from the ventral side, is plainly given off from $IIBr_2$, whereas at the dorsal side the lowest fixed pinnular appears to be connected usually with IIB_3, sometimes with $IIBr_4$; and the pinnulars connecting with $IIBr_2$ and $IIBr_3$ are usually not visible at the exterior. I have shown the mode of succession by the diagram (text-fig. 2), made from the ventral side, and the above fact must be remembered when studying it, as well as when comparing the dorsal and ventral views of the calyx in the same specimen shown by plate 1, figures 7, 8. The enlargement of the lower pinnulars ventrally is at the expense of the adjacent plates, and therefore the outer surface of the large interbrachial, contrary to the usual rule in the crinoids, is larger than the inner.

Professor Rowley, in Greene's Contribution to Indiana Paleontology[6] has described under the name *Stereocrinus? dilatus* a fragmentary specimen from the "Upper Helderberg" at the Falls of the Ohio, which may possibly be identical with this species; but it is impossible from the figure or description to make out any specific characters. Rowley noted, however, a marked difference between this form and *Stereocrinus*, and said that if he had better material he would not hesitate to erect a new genus for its reception.

Horizon and locality.—Onondaga limestone: Louisville, Kentucky, and Genesee County, New York.

Genus HADROCRINUS Lyon.

Plate 2, fig. 1.

Hadrocrinus LYON, Transactions American Philosophical Society, vol. 13, 1869, p. 445–451, pl. 26, fig. *a* (not *b* and *c*).—WACHSMUTH and SPRINGER, 1897, North American Crinoidea Camerata, pp. 327–8, pl. 24, fig. 1.

Lyon's definition and formula for the genus specified 2 by 5 plates in the first radial series, which in our terms would mean that it has only one primibrach; and he expressly stated in a note to the generic definition on page 445 that "the formula is intended to receive all crinoids with only two ray-pieces in the primary series." Although his first species in order of description was *H. plenissimus*, the only species which agrees with his generic definition in the above character

[6] Vol. 2, 1906, p. 8, pl. 3, fig. 5.

is *H. discus*. In the absence of any designation by the author, this should be taken as the type species for that reason. Furthermore Wachsmuth and Springer specifically declared *discus* to be the type,[7] and it therefore is the genotype by subsequent designation. *H. plenissimus* becomes the type of a new genus. A third species,

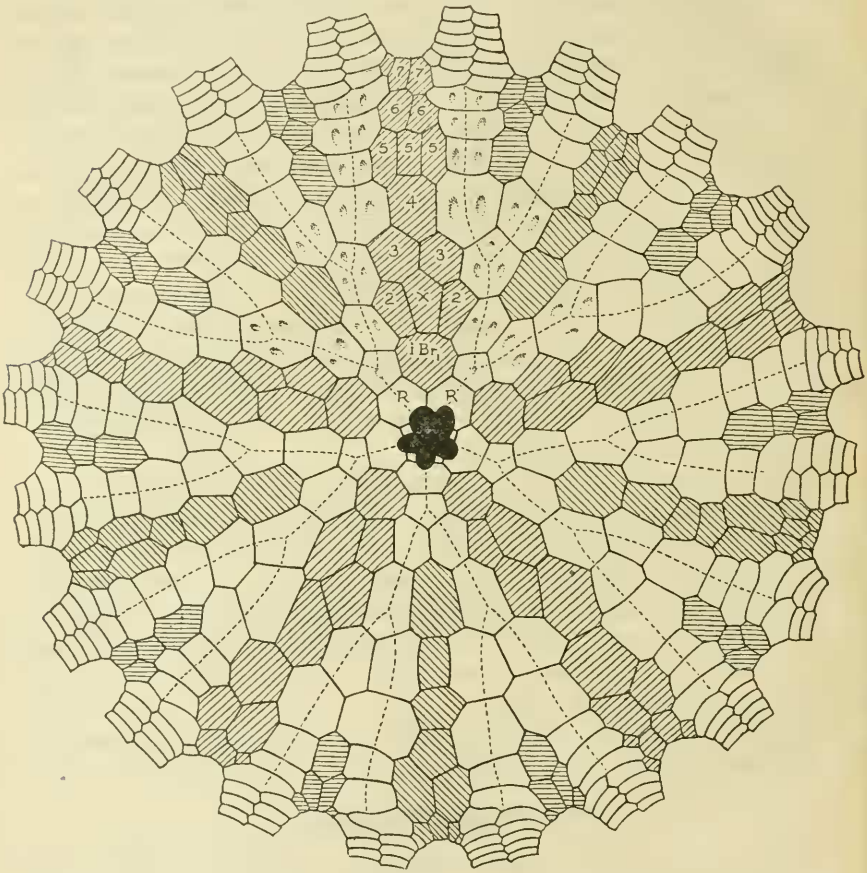

FIG. 3.—HADROCRINUS.

//// = i Br; \\\\ = i II Br; ≡ = i III Br; dotted line = R R and Br.

named by Lyon *H. pentagonus* in the text and *H. angularis* on the plate (fig. *c*), is founded on a fragmentary detached base, probably belonging to *Dolatocrinus grandis*.

The type species is extremely rare, only three specimens besides Lyon's original having been found. Although all imperfect, they exhibit the generic characters very satisfactorily, showing a wide-spreading calyx, with a low tegmen of rather large smooth plates. The bases of the very heavy biserial arms, restricted in number to

[7] N. A. Crin. Cam., 1897, p. 327

20, and therefore with only three orders of brachials, are well shown. The most remarkable thing about this form, however, is the condition of the base. With the radials included, there is a shallow basal cavity in which the basals are actually wanting in the specimens, but in one traces of the attachment of four small remnants of plates are seen inside the ring of radials (text fig. 4). Although their presence is indicated by crenulae in the small notches at the junction of the radials, the basals were practically eliminated from the calyx. They are entirely absent in the three specimens showing these parts, the proximal edge of the radials being deeply incised by the lobes of the axial canal. A huge column facet enveloped the entire base, including the radials and part of the next range; and the basals, thus shut out from the exterior, tended to disappear by atrophy. Such an almost complete elimination of basals has not been observed in any other Camerate crinoid, but is paralleled among the Flexibilia by the Silurian genus *Cleistocrinus* Springer, Crinoidea Flexibilia (pl. 38, fig. 2*b*), and as to infrabasals by several forms of the Ichthyocrinidae.

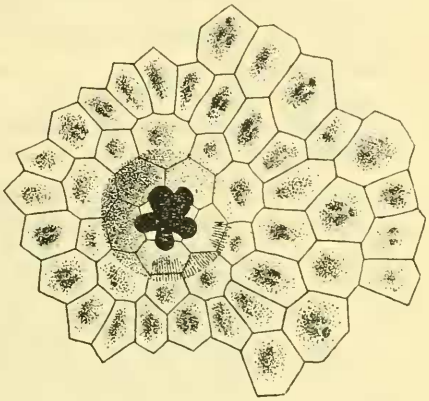

FIG. 4.—BASE IN HADROCRINUS DISCUS. REMNANTS OF ATROPHIED BASALS INDICATED BY NOTCHES; RADIALS INDENTED BY AXIAL CANAL AND COVERED BY COLUMN, AS SHOWN BY THE RADIATING STRIAE.

The radials and primibrachs are small, succeeded by large plates in the brachial series, which are singularly irregular in form and size. The half rays bifurate on the second secundibrach, which is followed by about four ranges of tertibrachs and one or two biserial pairs of arm brachials before the arms become free. The interbrachials are in six or seven ranges, beginning with a large first plate followed by two, with an extra plate interpolated on the posterior side. A narrow series, rarely exceeding two plates abreast, continues to the zone of the arm bases, but the fourth range consists invariably of a single plate. Similar plates are well developed in the second and third axils.

The calyx plates are smooth, entirely devoid of the intense sculpturing seen in *H. plenissimus;* but they have the very unusual character of broad, shallow median depressions containing smaller pits, which are double or triple on the radial series and single on the interradial, the triple pits being on the axillaries.

The type and only species of the genus is typically of large size, with calyx shallow and broad, the average diameter of three specimens being about 10 cm.

Horizon and locality.—Onondaga (Sellersburg) limestone: Louisville, Kentucky. A fragment belonging to the genus, and perhaps to the type species, has been found in Erie County, western New York.

HIMEROCRINUS, new genus.

HIMEROCRINUS PLENISSIMUS (Lyon).

Plate 2, figs. 2; plate 3, figs. 1–4; plate 4, figs. 1–4.

Hadrocrinus plenissimus Lyon, 1869, Trans. Amer. Philos. Soc., vol. 13, p. 445, pl 26, figs. *b* 1, *b* 2, *b* 3.—Wachsmuth and Springer, 1897, North American Crinoidea Camerata, p. 328, pl. 24, figs. 2 *a*, *b*.—Rowley in Greene, Contrib. Indiana Paleontology, vol. 1, 1903, p. 165, pl. 48, figs. 5, 6.

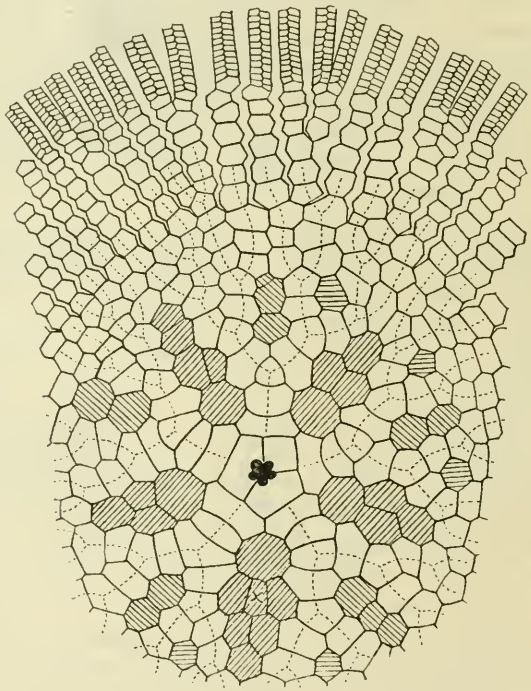

Fig. 5.—Himerocrinus.

//// = i Br; \\\\ = i II Br; ≡ = i III Br.
Dotted line = R R and Br.

The genus is founded on *Hadrocrinus plenissimus* of Lyon[8], which is the only known species. It attains a very large size, one of the largest of known Camerata, upwards of 20 specimens ranging from 10 to 15 cm. diameter of calyx. From a deep inverted cone involving the basals and radials —which are both large—the wall spreads outward in a graceful reversed curve to the arm bases, forming a broad,

[8] Amer. Philos. Soc., vol. 13, 1869, p. 445, pl. 26, figs. *b* 1, 2, 3.

shallow calyx, with a low tegmen composed of innumerable slightly tumid plates, resembling that of the Actinocrinoid genus, *Strotocrinus*.

The surface is marked by a most profuse and highly sculptured ornamentation, usually in the form of numerous intricate radiating ridges and furrows passing from plate to plate from the radials up which are sometimes broken up into pits less ornately arranged. The higher brachials leading to the free arms are marked by a conspicuous longitudinal ridge, with strong lateral processes. There is considerable variety in these surface characters, but they are too much influenced by conditions of preservation to be available for defining species.

The two special characters upon which the genus is founded are the primibrachs, and the enormous brachial extension of the calyx. These are thoroughly shown by the generic diagram (text fig. 5). While the primibrachs have the normal number of two, instead of a single axillary plate as in *Hadrocrinus*, they tend to assume an unusual condition, which is the reverse of what is seen in *Comanthocrinus*. One of the primibrachs is frequently much modified, but instead of the first, as in that genus, it is here the second, or axillary, plate that is unstable. In about half of the specimens it is more or less reduced in size, and singularly changed in shape and proportions, while in others it is of normal size and form all around. In some cases both forms are present in the same specimen. Lyon interpreted the structure of the IBr as being the same as in *H. discus*. In the intricate sculpture on many of the specimens the sutures are difficult to see, and his type being of that character he did not observe the presence of the two plates, which are evident in upward of 20 specimens. The modification in form of the axillary is seen in the diagram, which is made chiefly from an extraordinary specimen obtained since Lyon's time, having the calyx nearly intact, with a spread of about 15 cm., and the surface characters well preserved from the basal pit to the arm bases. It is finely shown by figure 1 on plate 3.

The irregularity in the axillary is reduplicated to some extent in the succeeding divisions, which are repeated to the number of 3 to 5, exceptionally 6, at intervals of two plates for the first three bifurcations, and longer higher up. After the third axillary the outer ramus of the ray and of the half dichotom remains single, while the inner ramus of the half dichotom branches, so that the number of arms is normally 16 or 17 to the ray, thus making 80 or more arms in all. The final brachial series bears a strong median ridge, and passes into a relatively small biserial arm. The ridges and arm openings are well shown in Lyon's figures *b* 2, and *b* 3, and I now have a specimen with the arms preserved for a considerable distance (pl. 4, fig. 1), which in their number and small size are in marked contrast to

the few massive appendages of the *H. discus*. It is in this respect strikingly similar to *Strotocrinus*, which with a greatly expanded calyx has similar small arms, in accordance with the fact, frequently observed in crinoids, that increase in size of calyx is often accompanied by a diminution in size of the arms.

The interbrachial plates are few and large, usually in three ranges of 1—2—1 in the interray, and 2, exceptionally 3, in single series in the second axils, with an occasional plate in the third. The anal interradius has usually an extra plate in the second range, but this may sometimes also occur in other interradii, so the differentiation is not certain.

The column of this genus partakes of a peculiar structure, more fully to be described under *Dolatocrinus*, whereby the nodal columnals are remarkably conspicuous, having a flanged peripheral rim overhanging and sometimes concealing the adjoining internodals, and being studded in varying number with projecting cogs resembling fins, while the internodals are thin and of less diameter.

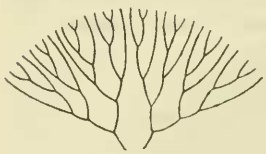

FIG. 6.—DISTRIBUTION OF ARMS IN HIMEROCRINUS.

All the specimens, including some 23 showing the basal cone only, in addition to the 20 above mentioned, seem to belong to the type species, with the possible exception of one. Hall's *Coronocrinus*, from the Manlius of New York, should be compared with this genus.

Horizon and locality.—The type and only described species is from the Onondaga (Jeffersonville) limestone, at Louisville, Kentucky.

Genus TECHNOCRINUS Hall.

TECHNOCRINUS NIAGARENSIS, new species.

Plate 5, figs. 1, 2.

Among collections made for me in western Tennessee in recent years are two forms belonging to the group under consideration, the occurrence of which carries the age of their genera back to earlier epochs than hitherto known. *Technocrinus* is typically an Oriskany fossil of the Lower Devonian, found heretofore only in Maryland and New York. It must now be credited also to the Silurian, on the evidence of the single specimen which I have figured under the above name. It was found in place in the Bob formation of the late Niagaran in the first bluff below Cerro Gordo, on the left side of the Tennessee River, in Hardin County, Tennessee; and it was associated in the same layer with *Lampterocrinus*, which is a thoroughly characteristic Niagaran form. The specimen is in good condition, showing all the generic characters very distinctly, and in addition to these the plates of the dorsal cup are surmounted by small, delicate spines, some

of which may have been movable. Several of these slender spines are shown in the figure, and well-defined shallow sockets are seen at the middle of some plates on which the spines are wanting. The plates of the cup are more or less marked by low connecting ridges, which become more prominent upward. The cup is a broadly rounded ovoid below, with a tendency to contract a little toward the arm bases. There were apparently 20 arms. Dimensions: Height, 20 mm.; width, 30 mm. Spines occur also on one of the Maryland species, *T. spinulosus*, but in the surface characters and form of calyx it is very different from this.

Horizon and locality.—Niagaran (Bob formation): Hardin County, Tennessee.

Type.—Of this and other new species herein described, Frank Springer Collection in United States National Museum.

Genus STEREOCRINUS Barris.

The other genus which must be set further back in the time scale is *Stereocrinus*, hitherto confined to the Middle Devonian, but which now turns up in the Helderbergian as a well marked species, for which I propose the name:

STEREOCRINUS HELDERBERGENSIS, new species.

Plate 5, figs. 3, 4.

In the material obtained by my collectors, Pate and Braun, from the Linden formation at various localities in Benton County, Tennessee, during a period of several years, were numerous isolated plates of an unknown Camerate crinoid, which by reconstructing a ray from these pieces I identified as *Stereocrinus*. Afterwards the fortunate discovery of a good calyx near Holliday confirmed the identification. The genus was founded upon specimens from the Hamilton of northern Michigan, and so far as I know it has not been recognized in the Onondaga beds of the Louisville area. In the Michigan form the calyx is strongly lobed in the zone of the arm bases, whereas in the present species there is no interradial depression whatever, and the arm bases form an almost continuous ring. Similar differences occur between species of *Dolatocrinus*. The plates of the cup in this species as found are usually smooth, with a low median ridge on the radial series, but when well preserved are marked by a sharp and fine striation. The tegmen is evenly convex, appearing too high in the figured specimen on account of pinching, and is composed of smooth plates. The specimen illustrated measures 30 mm. high and 42 mm. in diameter. Isolated plates indicate that a larger size was attained.

There is also fragmentary evidence of the existence of a large species of *Dolatocrinus* in the same beds with the *Stereocrinus*.

Horizon and locality.—Helderbergian (Linden formation): Benton County, Tennessee.

Genus DOLATOCRINUS Lyon.

The definition of the genus sufficiently appears in the antecedent analysis. While it is there stated that the anal side is not differentiated, and elsewhere that the symmetry of the dorsal cup is not disturbed by anal structures, these statements must not be taken too literally. While it is true that there are usually on the dorsal side no extra plates analogous to those in the first or second interbrachial ranges of the posterior interradius which are commonly called "anal plates," yet there is unquestionably more or less disturbance of the *Dolatocrinus* calyx by reason of the position and growth of the intestine, sufficient to produce in the calyx as a whole a certain bilateral symmetry. The anal tube is always decidedly subcentral; and while the interray toward which it inclines may in most cases have no increase in number of plates, a comparison of numerous specimens shows that the posterior interradius is very often appreciably wider than the others, and its plates larger. Little is known of the arms of *Dolatocrinus*, they having only been seen in two or three specimens, except in the New York species described by Hall as *Cacabocrinus troosti*, and referred to *Dolatocrinus* by revisors, which has branching arms, and should stand as a different genus under Troost's name adopted by Hall, or some other. Aside from this, all the species probably have simple, biserial arms, and they must have been extremely fragile.

Dolatocrinus is notable for the prominence of its first interbrachial, which is the largest plate in the calyx, conspicuous alike for its size, and in most species for its elaborate radiate sculpturing. It is usually followed by one or two diminishing plates tandem, while the other plates which appear in the interbrachial areas are fixed pinnulars, some of which are so large as to lose the semblance of their primitive function. This is the case with *D. grandis*, which has no interbrachials beyond the first, but the space which in other species is occupied by a second interbrachial is taken by two large pinnulars resting in part upon its angular distal face. The genus differs from others having a similar incorporation of pinnules in their order of succession. In *Comanthocrinus*, with uniserial arms, the pinnulation begins on the second secundibrach, followed by one alternating on the third, and beyond that on both margins of successive brachials. In *Scyphocrinus*, also uniserial, the succession is alternately on secundibrachs 2, 4, 5, 6, 7, etc. But in *Dolatocrinus*, with biserial arms, the first incorporated pinnule leads from secundibrach 1, after which the succession is alternately on 2 and 3, and beyond that on each brachial of the biserial pairs.

The column of *Dolatocrinus* has some striking peculiarities not observed in crinoids outside of this group, but which it shares with that of *Himerocrinus*. It is composed of very thin columnals, some

of which (the internodals) are plain disks of uniform thickness for their full diameter; alternating with these at different intervals are other columnals (the nodals) also thin in their median portions, which are of greater diameter than the former, and have at their circumference a flange which projects at either side like the tire of a wheel, to a width at least equal to the thickness of one internodal. Thus two nodals may abut at the exterior by their flange-like rims so as to arch over the intervening internodal and completely conceal it from view; or, a greater number of internodals may be interposed, up to 6 or 8 or perhaps more, in which case the nodal stands out in relief, conspicuous by its higher level and greater thickness. Furthermore, the nodals themselves are surmounted by certain singular fin-like cogs transverse to their periphery—that is, longitudinally parallel to the column. These occur to the number of three, five, or sometimes more, to each nodal, of which those of successive nodals may or may not coincide in position; if they do, the column takes on an angular outline. The cogs may be limited to the width of the nodals to which they are attached, or they may extend either way for the span of several internodals, perhaps in some cases connecting and forming continuous serrated longitudinal ridges along the column. Some of these cog-like projections are relatively high, even equaling the diameter of the column, and they evidently in some cases form a continuation of the knife-edged ridges on radials and primibrachs in forms like *D. spinosus*, *D. marshi*, etc. Owing to the thinness of the columnals, the peripheral flanges of the nodals are held by a weak connection, so that in the fossils they may often be broken off, leaving only a continuous series of columnals of the same size as the internodals (pl. 9, fig. 3).

Specimens with any portion of the column attached, or even any considerable length of detached columns, are extremely rare, so that we have little information as to the distribution of the nodal columnals throughout the stem as a whole; but from the fragments available, and from analogy with the mode of growth of the stem in the crinoids generally, it is probable that in the proximal parts of the stem the nodals are contiguous and conceal the interpolated internodals under the arch formed by their flanges, while toward the distal end the internodals increase in number, and the intervals between the nodals become longer. Thus in the part of the stem proximal to the calyx shown in figure 2 of plate 10 the nodal columnals are in close contact, concealing the internodals which may be seen at the broken extremity, and the projecting cogs form continuous ridges. In figure 1 there are gaps between the nodals in which internodals are seen, and the cogs do not always coincide in alignment, both of which may be due to disturbance after death. In various sections of stems figured on plates 9 and 10 the intervals

in their natural condition are shown, some with as many as 12 internodals, which were probably from the distal portions. Among these fragments also are shown some good examples of the form and proportions of the nodal columnals, and of the cog-like processes, as above indicated.

Sections of stem from near the root are found having strong radicular cirri more or less radiately arranged; and in two instances, clearly belonging to this genus, a cirrus appears in place of one of the cog-like processes, which suggests the idea that these outgrowths of the nodal columnals are analogous to cirri.

Lyon observed this peculiar type of column, and gave a description of it, with a figure, in his paper of 1869 in the Transactions of the American Philosophical Society (p. 451, pl.. 26, fig *h*); but with the terms he used his description is rather hard to understand.

There is in the species of this genus a marked instability in the form and proportions of some of the principal calyx plates, as well as in some other characters. There is much variation in size of the radials, brachials, and interbrachials, not only among different specimens of the same species, but also among the different rays of the same specimen, so that the relative shape and size of these plates are of little value in the definition of species. Even in some of the best defined and most constant Onondaga species, such as *D. spinosus*, we find the conspicuous first interbrachial undergoing change from broadly truncate above to elongate and almost acuminate, without apparently affecting any of the other characters; and in *D. lacus* the number of interbrachial ranges may vary among specimens otherwise almost counterparts. Many other examples could be cited, including abnormal specimens, rather frequent, especially in Hamilton species, such as those with four rays, with a sixth plate in the radial circlet, etc.; and the instability in these and other respects must constantly be taken into account in considering the definition or identification of species of this genus.

Genotype.—*Dolatocrinus lacus* Lyon.

Distribution.—Onondaga: Louisville area, and Ohio; perhaps Helderbergian, Tennessee.

THE SPECIES OF DOLATOCRINUS.

In the following discussion of *Dolatocrinus* and its species there will be frequent reference to a few works for which it may be convenient to use abbreviations; these are:

Miller and Gurley. Bulletins 4 to 12 of the Illinois State Museum, 1894 to 1897. Cited: "Miller and Gurley, Bull. 4, 1894, etc."

Wachsmuth and Springer. North American Crinoidea Camerata. Memoirs Museum of Comparative Zoology, Harvard, vol. 20, 1897. Cited: "Wachsmuth and Springer, N. A. Crin. Cam. 1897."

ROWLEY; in GREENE. Contribution to Indiana Paleontology, vol. 1; issued in 20 parts, Feb., 1898, to Sept., 1904, continuously paged, pp. 1–204, plates 1–60; and three parts of vol. 2, July, 1906, to Nov., 1906, pp. 1–38, plates 1–9. Cited: "Rowley in Greene, 1903, etc."

The genus *Dolatocrinus* is remarkable among all Camerata for the extraordinary number of species which have been described under it from a single horizon within a small local area. The total number of named species and varieties for all areas is 77, all from the Middle Devonian, of which 15 are from the Onondaga and 62 from the Hamilton. Sixty-five belong to the Louisville area, and of these, 49 species and 4 varieties are described from the Hamilton alone. The crinoid-producing exposures in the Hamilton beds of this area are of very limited extent, being confined principally to a few miles opposite Louisville, and along Silver Creek and other streams in Clark County, Indiana, from which the types of nearly all the 53 alleged species and varieties have been derived. The specimens are almost never found with any part of the arms attached, and we know nothing of the structures distal to the calyx, except that the arms are biserial and probably always simple. Hence the descriptions are necessarily restricted to characters observed in the calyx alone, which in this genus is of the most simple construction, having a nearly pentamerous symmetry, so that we are without the benefit of characters for discrimination usually afforded by the presence of anal structures. The slight differences occasionally noticed in the second or third ranges of interradial plates are inconstant and mostly sporadic.

The occurrence of such an incredible number of species of one genus, from a single horizon at the same locality, is in the highest degree improbable; and the statement of the foregoing facts alone is sufficient to put the list under suspicion. It is of importance that the character of the crinoidal fauna of this celebrated locality should be correctly understood, in order that authors and students may not be misled into erroneous conclusions regarding it.

The greater part of this multiplication of specific names is due to the activities of Miller and Gurley, who, during the years 1894–1897, published in the Bulletins of the Illinois State Museum 37 species of *Dolatocrinus* from the Hamilton beds alone, in addition to four from the underlying Onondaga, all from the vicinity of Louisville. By the work of these authors, chiefly in the publications mentioned, and of Mr. Miller alone in the reports of the Geological Surveys of Missouri and Indiana, several hundred species of crinoids and blastoids were described and illustrated, mainly from specimens in the rich collection accumulated by Mr. Gurley, which he afterwards placed at the service of science by donating it to the Walker Museum of the University of Chicago. By these means a great number of

new and instructive forms were brought to light, and a valuable addition was made to our knowledge of the prolific crinoidal faunas of the interior continental basin. Most of the specimens were obtained by Mr. Gurley through purchases from local collectors, some of whom were not geologists, and sufficient care was not always taken to determine the exact horizon from which they were derived; so that in several instances the stratigraphic position assigned to the species in the published descriptions is not correct. This is notably the case with some of the most conspicuous forms of the Louisville area.

Subsequently Mr. George K. Greene, the veteran collector at New Albany, Indiana, on the Ohio River opposite Louisville, published a series of pamphlets extending through the years 1898–1906, which collectively formed the volumes entitled: Contribution to Indiana Paleontology, for the purpose of illustrating his extensive collection of corals and crinoids—the work upon the latter being intrusted to Prof. R. R. Rowley, of Louisiana, Missouri. This resulted in the proposal of 16 new species and varieties of *Dolatocrinus*, likewise all from the Louisville area.

The type and another early species had been published by Lyon, and seven others from New York, Canada, and Michigan by Hall, Whiteaves, and Barris, respectively. Of those published by Wachsmuth and Springer in their Monograph of the North American Crinoidea Camerata in 1897, some had been anticipated by the descriptions of Miller and Gurley while that work was going through the press, and it is necessary for the correctness of the record that the synonymy of these should be definitely stated. Two species from Michigan were published by Miss Elvira Wood in 1904. I am informed that at least two new species and as many varieties from New York are to be published by the State museum; and I am reluctantly compelled to swell the list by adding four new names on my own account.[9]

Recurring again to the numerous Hamilton species published by Miller and Gurley: In order to facilitate the describing of species, they at the outset laid down as an ironclad rule that the number of arms alone should constitute an invariable specific character, so that

[9] The differences in the known crinoidal faunas of the several Hamilton areas of the Middle Devonian of this continent are very striking. At Louisville *Dolatocrinus* is the leading genus, followed by *Megistocrinus*, *Nucleocrinus*, *Codaster*, etc., but no sign of *Melocrinus* or of any Flexible crinoid; in Callaway County, Missouri, *Melocrinus* occurs, and an Ichthyocrinoid of the genus *Dactylocrinus*, but no *Dolatocrinus* or *Megistocrinus;* in Iowa *Megistocrinus* and *Melocrinus* and a notable new Ichthyocrinoid, but no *Dolatocrinus* in northern Michigan, *Dolatocrinus*, *Megistocrinus*, *Nucleocrinus*, and *Codaster*, of species mostly well differentiated from those of the Louisville area; in Wisconsin, *Melocrinus* closely similar to the Missouri species, forms which also extend far to the north in the McKenzie Basin, Canada; in the last four areas, not including the Canadian, species belonging to the Flexibilia occur, of different forms in each. In western New York and Ontario, *Dolatocrinus* and *Megistocrinus* closely related to the Louisville forms occur; but in addition to these an extraordinary assemblage of other forms not represented in either of the other areas, which are soon to be described in a Memoir by the the New York State Museum.

by this means they were relieved of the trouble of comparison with species otherwise similar, which they usually declared to be unnecessary. Thus in Bulletin 8, page 46, in describing *D. charlestownensis:*

It is, of course, unnecessary to compare it with any other described species, because the arm formula alone distinguishes it.

This plan placed the describing of species upon a sure mathematical basis; but it had its limitations. The range of variation in number of arms in a single otherwise constant form of *Dolatocrinus* may be from 10 to 20, which was soon in danger of being used up. So the authors went a step farther, and evolved another scheme of infinite possibilities, namely, that not only is the number of arms an invariable specific character, but also the mode of grouping of the arms among the five rays—so that newly acquired specimens not otherwise distinguishable from species already described could readily be made the types of new species upon this character alone. Thus they say in the ninth Bulletin, page 47:

This species is distinguished from all other 16-armed species * * * by the arm formula. For example, the arm formula in *D. coelatus* is 4–4–4–2–2; in *D. nodosus* it is 4–3–3–3–3; in *D. salebrosus* it is 4–3–2–3–4; in *D. arrosus* it is 4–4–3–3–2.

And on page 51:

It can be of no service to compare this with any species having a different arm formula, for that alone distinguishes it.

The beauty of this plan will be evident when we consider that if we take only the most usual variations, caused by the addition of one or two arms, thus giving 2, 3, or 4 arms to the ray, there would be 120 different permutations of these numbers among the five rays of a crinoid, each of which under the authors' latest rule would establish a distinct species; that is to say, 120 species under any otherwise defined form. Every one of the dozen or more recognizable Hamilton forms of that locality may exhibit similar variations in number and arrangement of arms; so that with sufficient collections there would be as the logical result of this process, consistently followed up, about 1,500 possible species of this one genus, in a single formation 8 feet thick, and at the same locality.

Now it is a fact abundantly established that a character which is available for the differentiation of species in one group or genus, or in one formation or locality, may as a result of different conditions be utterly worthless in others. This is notably true in regard to the number of arms in the crinoids. Among the recent forms, especially the comatulids, variation from 10 to 20 arms is not uncommon, while on the other hand a definite number of arms is constant for many large groups.

In certain prolific and extremely well-marked Carboniferous species, such as *Macrocrinus verneuilianus* and *Dizygocrinus rotundus,* there is a considerable range of variation in number of arms (which

Miller and Gurley utilized, however, by making new species for all of them), whereas in many other Batocrinoid genera the number is generally constant for the species. Among the Onondaga species of *Dolatocrinus* the number of arms appears to be usually constant and well correlated with other characters. In the Hamilton the genus reached its acme of development, resulting in an enormous increase in number and variety, followed, as usual in such cases, by extinction. It was a period of active mutation. Several extremely well-marked types were produced, which may readily be distinguished from the Onondaga forms and from one another. Some of these, which no experienced paleontologist would fail to recognize at a glance, include variations in number and grouping of arms and in minor details of surface ornament which, if regarded as essential, would result in making a new species for almost every well-preserved specimen that turns up. In fact, that is what actually occurred as to a large part of Miller and Gurley's Hamilton species; for in the Gurley collection, containing all the material used in their study of this genus, 18 of their species are represented only by the single type specimen, there being no duplicates except in the other 19. And to show how the use of the arm character would work out in practice, there are in my own collection upward of 20 specimens belonging to the most prolific Hamilton form of the locality which have arm formulas different from that of any of Miller and Gurley's species, and every one of them, under their rule, would have to be made the type of a new species.

The recognition of the several well-defined and definable Hamilton types will result in the reduction of the species to a reasonable number, within the bounds of probability. I shall attempt to point them out, and to give the names which by reason of priority should be attached to them. Much of the matter contained in the lengthy descriptions (often tedious repetitions of generic characters) is of no practical service for the discrimination of the species. For any valid species it ought to be possible to point out some one definite character, or combination of characters, not due to individual variation or sporadic occurrence, by which it is distinguished and contrasted with others. Supposed species for which this can not be done should be merged in the nearest one that is well defined.

The characters which have been chiefly considered in the differentiation of species in this genus are the following:

Form.—The general form and proportions of the calyx are useful characters which mark several well-defined types. It may be rather high cup-shaped, with vertical sides and flat base; bowl-shaped or hemispheric, expanding by a regular curve from a narrow base to the arms; basin-shaped, with nearly straight sides, spreading at a wide angle from a truncate and concave base; depressed bursiform, constricted below the arm bases, the sides curving inward to a broad

flat or concave base. Along with these various shapes, but not always concurrently with particular forms, the tegmen may vary from nearly flat to convex or conical; deeply lobed or sloping evenly; with plates well defined, or rather obscure on the smooth surface; with surface granular, covered with small pustules, sharp or rounded nodes, or strong spines. The base may be sharply excavate into a deep or shallow pit enclosing the column, broadly concave, flat, or protuberant. In some forms the tegmen is remarkably constant and characteristic; in others, especially the large bursiform type, it is subject to much change due to pressure in fossilization.

Surface ornament.—There are upon the plates of the dorsal cup two kinds of sculpturing: (1) A longitudinal median ridge following the radial series, which may be limited to a few of the lower plates or may traverse the entire distance to the arm bases; may be low, rounded, inconspicuous, or high, sharp, and very prominent; or it may be absent altogether. It is formed with nodes at the centers of the plates as nuclei, which may be elongated until they connect at the sutures, or may be connected by a rounded neck; if the connecting neck approaches the size of the nodes, the ridge may be called continuous, and if very much smaller and inconspicuous, it may be called discontinuous. Again, the central nodes may be substantially isolated, but even then there is usually some trace of a connection marking the course of the buried nerve cords. (2) A secondary sculpturing which consists of more or less continuous radiating striae, straight or wrinkled, or lines of small pustules, passing from plate to plate, tending to form concentric triangles; or of nodes or pustules not radiately arranged. Primarily the ridges connecting the centers of both radial and interradial sets of plates are the external representatives of the nerve cords which innervate the growing skeleton, and the triangular arrangement results mechanically from the mutual relations of the plates. With age they may become variously modified by secondary growth, reduplicated, intensified, or broken up into nodes by which the original fine lines are interrupted, obscured, or obliterated. These processes will produce extremes of the two types of sculpture, between which there may be an infinite number of combinations in which the two are more or less intermingled. Sometimes the striae are bent or wrinkled, making a vermicular kind of ornament; and in some cases there are neither definite striae nor nodes, but all plates are tumid and radiately furrowed. If certain lines of the triangles are accentuated, a stellate figure is produced around the base. On account of intergradation between the different types, too much importance must not be attached to the surface ornament. Even Miller and Gurley had some doubt about it, for they said in Bulletin 4, page 25:

> We are satisfied the sculpturing is not uniform on specimens belonging to the same species.

Nevertheless they afterwards often stated as to a new species that it "differs from all others in surface ornamentation and number of arms." Unless fairly definite stages of these surface modifications can be correlated with some other character, I am unable to regard them as of much practical value in the discrimination of species. (See further under *D. incisus* and *D. asperatus*.)

So-called "azygous side."—This was Miller's term for what other authors usually call the posterior, or anal, interradius. In this genus that side is usually not differentiated in the dorsal cup by any increase in the number of plates, but may be in some cases by the greater size of corresponding plates. The first and second ranges of interbrachials consist normally of one plate each, from which number they rarely vary; slight differences occasionally occur in the third range, but these are sporadic, not constant for the species, and may be disregarded in the descriptions.

Pinnule openings; "ovarian apertures"; or "pores."—Much has been said in the specific descriptions about the openings through the calyx wall which occur in varying numbers in the zone of the arm bases. They have been called "ovarian apertures" by Miller and Gurley, and "respiratory pores" by Wachsmuth and Springer. As already stated, I have elsewhere[10] shown by conclusive evidence of specimens in which the parts are perfectly preserved that these slit-like openings or pores, which occur also among the Batocrinidae, Platycrinidae, and the non arm-branching Camerata of other families, are the openings for pinnules which are to a greater or less extent incorporated in the calyx, and emerge directly through the wall along the margin where the dorsal and ventral structures meet, analogous to the oral pinnules of the Recent crinoids. It is probable that they occur in all species of *Dolatocrinus*, unless perhaps in some where the arms become free directly upon the first secundibrach. In several cases where the species were described as without "ovarian pores," subsequent inspection has disclosed their presence; and their apparent absence in any specimen may be due to their being obscured by silicification or covered by matrix, or to their inconspicuous occurrence. They differ in shape and size in different species or groups of species; in some they are indicated by long slits, well exposed and visible at a glance; in some they are very small and lie close under the edge of the arm, but are absent in the wider space between the rays, in which case, especially when there is a rugose surface, they are hard to see.

The elongate slits represent the ambulacral grooves leading to the openings, from which the minute covering pieces have fallen away, a shown by figures 4 and 10 on plate 1.

[10] On the genus *Scyphocrinus*, 1917, pp. 33–37; 40–46; pl. 9, figs. 5*a*, *b*, 6; see also pl. 1, figs. 4, 10, and pl. 2, figs. 3, 4, herein.

The number of visible openings depends upon the extent to which brachials are incorporated, as has been shown in regard to the two species of *Comanthocrinus*. If the arm becomes free on the first secundibrach, there may be no pores through the calyx wall, or only a single one at one or both sides of the arm-base; if higher secundibrachs are incorporated, the number correspondingly increases. In *D. grandis* (pl. 7, figs. 2, 5) the biserial arm is incorporated for a distance of several pairs of brachials following the third secundibrach; a fixed pinnule leads from $IIBr_1$, on the outer side of the dichotom, followed by one on $IIBr_2$, inner side, next by one on $IIBr_3$, outer side, and then by one for each margin of the biserial pair, each of which leads to an opening. Therefore when one pair of brachial ossicles succeeding $IIBr_3$ are incorporated, there will be 6 pores between the rays and 4 between their divisions; and with further incorporation of arm brachials the number of openings will be increased to 8, or even 12. In *D. bulbaceus* only one small pore is present for each arm; in *stellifer* and *amplus* there are always 2 for each arm, and from 2 to 4 for each interradius.

Number of arms.—With the foregoing category of available characters to choose from, it ought to be practicable to find correlations of sufficient constancy to define the species without resorting to anything so purely arbitrary as the number and grouping of arms, standing alone, in forms where this character is clearly subject to great individual variation. I do not wish to be misunderstood on this point, and it must not be supposed that I am denying the importance of the number of arms as a general proposition. On the contrary, it is a character of great value and of wide application, representing as it does progressive stages in the ontogeny of the crinoids which often become fixed, and furnish decisive criteria in the separation of groups. The entire Larviformia division of the Inadunates is characterized by having the arms in the primitive stage, without any axillary plate in the ray, and therefore five in number. The change in other groups from 10 to 20 arms, due to a second bifurcation in all the rays, indicates a certain progress in calyx development by increase in ray capacity that probably correlates with other facts. Where the change is of less degree—such, for example, that only one of the two arms in each ray bifurcates—but according to a definite plan, it may be a good character. For instance, the 15 arms, 3 to each ray, of *D. triangulatus* of the Michigan area, constant as I have it in 23 specimens, and correlated with a definite form and proportion of calyx and style of ornament, is a good character to help distinguish it from somewhat similar forms having a constant number of 2 or 4 arms to a ray. The 10 arms of *D. grandis* is a perfectly reliable character as against the 20 arms of *D. spinosus*, or the 30 arms of *D. exstans*, or the 40 of *D. multibrachiatus*. But if a specimen of *D. spinosus* happened to have

19 or 21 arms, or one of *D. multibrachiatus* 37 or 43, that would not make them different species, since the general morphological condition would remain the same. It is even true that in some groups species are marked by increase in the number of arms occurring in less than all the rays, as in *Agaricocrinus* and *Megistecrinus*, where the arms may be variously grouped, yet the groupings are according to a definite plan, having a certain relation to the bilateral symmetry of these crinoids. But it is in forms of simple construction like *Delatocrinus*, when the change in number of arms from 10 or more to 20 or less is effected by the addition or subtraction of one or two arms in one or more rays at random, without any definite order or system, and this in forms otherwise similar, that such differences must be wholly disregarded in the definition of species.

The crinoids from Louisville and vicinity of Onondaga age have been derived chiefly from rocks exposed at the Falls of the Ohio River which lie below the hydraulic limestone, being of a formation of crystalline limestone 20 to 30 feet thick, now known locally as the Jeffersonville limestone. Those of the Hamilton are from the upper part of a limestone formation, 8 feet thick, called the Sellersburg limestone, of which the most productive exposures are along Silver Creek in Clark County, Indiana, above the hydraulic limestone. Bear Grass Creek on the Louisville side was in former years a well-known locality for Hamilton crinoids, from which many fine specimens were obtained by the early collectors. For a lucid account of the stratigraphy and local occurrences of the region see Dr. R. S. Bassler's paper of 1908 on The Nettleroth Collection of Invertebrate Fossils.[11] For convenience I use the expression "Louisville area" to designate the general locality, including the Falls of the Ohio and the exposures on both sides of the river at Louisville, and along Silver Creek in Clark County, Indiana.

The relations of the recognizable species are shown by the subjoined analytical keys, the Onondaga and Hamilton species being treated separately. Following these I have listed the species for the respective formations with the synonyms under each. The number of species is thus reduced to 12 for the Onondaga and 23 for the Hamilton. To avoid needless repetition, it should be noted that the types of Miller and Gurley's species (except three that were lost) are in the Walker Museum at the University of Chicago, and those of Rowley are in the American Museum of Natural History in New York; and that all the species described by both these authors are from Louisville, Kentucky, and vicinity. The types of Hall are in the American Museum; those of Miss Wood in the United States National Museum; and those of Lyon, Barris, Wachsmuth and Springer, as well as the new material here figured, are in the author's collection, now in the United States National Museum.

[11] Smithsonian Miscellaneous Collections, vol. 52, p. 2, pp. 121–152.

ONONDAGA SPECIES.

[Valid species in italics; synonyms in roman.]

With 10 arms.
Calyx small.
High cup-shaped, with broadly truncate base; central nodes small.
Radiating striae few and coarse.
Tegmen low; pinnule openings prominent.
Sides of cup nearly vertical ..... *D. lacus.*
—approximatus.
Sides of cup sloping inward from broad base.. *D. pyramidatus*, new species.
Depressed basin-shaped, sides sloping outward; broadly curving base with small pit.
Radiating striae or wrinkles fine and numerous; radial ridges low or wanting; no nodes ..... *D. ornatus.*
Surface smooth; tegmen and cup evenly rounded to a globose contour ..... *D. rotundus*, new species.
Calyx medium sized.
Doubly conical, with broad base; sides sloping at wide angle to arm bases; sharp median ridge on radials and IBr.
Radiating striae coarse or wanting.
Tegmen rather low ..... *D. speciosus.*
Radiating striae fine and sharp.
Tegmen higher; pinnule openings prominent ..... *D. marshi.*
Calyx large, subhemispheric.
Base truncate, deeply excavate, involving all of radials; iBr single, angular above, followed by two plates which are pinnulars; median ridge on radials and IBr obtuse or absent; surface of cup-plates strongly wrinkled. Tegmen high convex; pinnule openings large and numerous.. *D. grandis.*
—excavatus.
— var. unicarinatus.
— fossatus.

With 20 arms.
Calyx large.
Base shallow concave, with small pit; cup-plates ornamented with fine radiating striae; median ridge on radial series strong, keel-like.
Tegmen moderately convex; pinnule openings few and prominent.
Median ridge confined to radials and IBr. Tegmen bearing strong spines ..... *D. spinosus.*
—curriei.
Median ridge continuing to arms. Tegmen without strong spines ..... *D. insuetus.*
Insufficiently defined; similar to *spinosus* in dorsal cup, but tegmen unknown ..... D. lamellosus.
Base broad and flat, with shallow pit not including radials; surface smooth, small node or spine on IBr, exceptionally a keel-like ridge ..... *D. major.*

With more than 20 arms.
Calyx large.
Base protuberant; tegmen bearing long spines. Arms about 30..... *D. exstans*, new species.
Base shallow concave, with small pit, similar to *spinosus*, but with about 40 arms..... *D. multibrachiatus*.

DOLATOCRINUS LACUS Lyon.

Plate 5, figs. 6, 7.

Dolatocrinus lacus Lyon, Geol. Surv. Kentucky, vol. 3, 1857, p. 482, pl. 41, figs. 2*a-e*.—Billings, Canad. Org. Rem., Dec. 1, 1858, p. 29, text-figs. 13–18.—Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 9. pl. 1, fig. 4.—Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 311, pl. 261, figs. 6*a-c*.

Dolatocrinus approximatus Miller and Gurley, Bull. 4, 1894, p. 25, pl. 3, figs. 4–6.

This, the type species of the genus, has been thoroughly described and illustrated in the literature. The chief points to observe are its almost rectangular outline in vertical section, the broad and flat base, and relatively high calyx with low tegmen; the ornament is by small central nodes on the lower plates, and a few prominent raised lines, producing distinct stellate figures. The species is rather below medium size, ranging from 15 to 20 mm. high and 20 to 25 wide. In typical specimens the height to width of calyx is about as 1:1.25, and the width at the flattened base about equal to that at the arms; but there is variation from this to 1:1.5, the lower forms of greater width having more curvature at the sides and relatively narrower base; there is also variation toward fine instead of coarse radiating lines upon the plates. A remarkable enlargement of the base in some specimens beyond anything heretofore known in this group seems to indicate a distinct allied species, *D. pyramidatus*.

Throughout all these variations one constant character prevails, which always arrests attention, and that is that the two or three secundibrachs, with sometimes a biserial pair of arm-ossicles, are incorporated in the calyx in such a way as to produce four conspicuous pinnule openings in each interradius, and two, rarely four, in the spaces within the rays; in the latter case they are more crowded. These prominent pinnule sockets, and the broad flat base, give to the crinoids of this type, notwithstanding their small size, a very characteristic aspect.

Horizon and locality.—This form occurs both at Louisville and in the Onondaga limestone at Columbus, Ohio; and the 30 specimens which I have from the two localities conform closely to the type, subject to the variations mentioned; they show no tendency to modification in the normal number of 10 arms, the solitary specimen on which Miller and Gurley based their 11-armed synonym, *approximatus*, being a mere sporadic occurrence.

S. S. Lyon gives the horizon of *D. lacus* as "above the hydraulic beds," but says that some specimens occurred at the base of the hydraulic limestone. All the specimens in the Lyon collection when I purchased it, including the type, were labeled "Upper Helderberg;" and Colonel Lyon's son, Victor W. Lyon, who collected many of them, said that to his personal knowledge they came from the "upper part of the *Nucleocrinus* bed." George K. Greene labeled all the specimens which I obtained from him as "Upper Helderberg;" and the occurrence of the species at Columbus, Ohio, confirms the horizon as Onondaga. The statement in Lyon's text must have been due to oversight or confusion of notes.

DOLOTACRINUS PYRAMIDATUS, new species.

Plate 5, figs. 8–11.

Of the type of *D. lacus*, but with base enlarged to a width greater than that of the calyx at the level of the arms, so that the slope of the nearly straight sides is inward at less than a right angle. The first primibrach and first interbrachial are bent inward below to form a part of the flat base, the calyx resting upon the small nodes upon these plates. This very unusual contour occurs in three well marked specimens; the largest of them, which abnormally lacks an arm in one ray, is about 22 mm. high by 28 mm. wide at the arm level, and 31 at the base. Pinnule pores are very conspicuous, 2 and 4 to the interspaces.

Horizon and locality.—Onondaga (Jeffersonville limestone): Louisville, Kentucky.

DOLATOCRINUS ORNATUS Meek.

Plate 6, figs. 1–4,

Dolatocrinus ornatus MEEK, Proc. Acad. Nat. Sci. Philadelphia, 1871. p. 57.—MILLER and GURLEY, Bull. 4, Ill. St. Mus., 1894, p. 181, pl. 2. figs. 7–9.

Described by Meek without illustration, but well figured by Miller and Gurley, their figure corresponding in all essentials with the type in Columbia University, which is here figured for the first time. The species is not uncommon in the Onondaga rocks at Columbus, Ohio, and I have it also from western New York. From the Ohio locality I have a number of good specimens, averaging somewhat larger than that of Miller and Gurley's figures. It is, however, typically a small species, and differs decidedly from the other small Onondaga species, *D. lacus*, in the relatively lower, broader, and less angular calyx, and in its peculiar sculpturing by means of very fine radiating costae, which become bent and wrinkled in various ways, producing a sort of vermicular style of ornament. In most specimens a low continuous radial ridge is defined, but in some it is entirely wanting. The tegmen is remarkably constant among the

specimens both of the original species and the variety, being broadly and rather deeply lobed, and covered over the entire surface with numerous small projecting tubercles. One little point peculiar to this species is a sort of overhanging lip from the edge of the tegmen between the rays; it seems to be present in all the variations.

This form persisted into the Hamilton, where it increased in size, and underwent some striking changes in surface markings, while retaining with thorough constancy the chief distinguishing characters of the type. This was described by Miller and Gurley as a variety, *asperatus*, but in view of the difference in horizon, it is better treated as a species, and it will be listed as such under the Hamilton.

Horizon and locality.—The type of *D. ornatus* is in Columbia University; and the species is from the Onondaga limestone at Columbus, Ohio, and in western New York.

DOLATOCRINUS ROTUNDUS, new species.

Plate 5, figs. 12, 13.

This species is founded upon a single specimen, of a type differing from all others in having a perfectly round calyx, without angularities or projections of any kind; the surface is smooth, and there is no lobing, or depression, except a slight one for the column facet. It has 10 arms; although surface preservation is good, pinnule openings are not discoverable between the arm bases. The dimensions are 25 mm. high by 30 mm. wide, being slightly contracted vertically; 17 mm. of this height is from the base to the middle of the arm openings, leaving the tegmen low in proportion to the total height. The specimen is in good condition, and these characters must be accepted as definite structures, there being no other species of which it can be considered a variant.

Horizon and locality.—The type specimen came from the Onondaga (Jeffersonville) limestone at the Falls of the Ohio River at Louisville, Kentucky, below the hydraulic limestone.

DOLATOCRINUS SPECIOSUS (Hall).

Cacabocrinus speciosus Hall, 15th Rep. New York State Cab., 1862, p. 109 (137)
Dolatocrinus speciosus, Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 323, pl. 26, figs. 4*a*, 6.

Hall gave no figures of the several species described by him in the fifteenth report under *Cacabocrinus*, but this one was well illustrated by Wachsmuth and Springer from a somewhat eroded New York specimen answering the description. In form of calyx it represents a type that might be called doubly conical, sloping both ways from the zone of the arms, and truncated at the broad base, where the width is about two-thirds that at the arm level. The wide, rather angular, outward slope of the sides from the plane of the base gives a basin-shaped contour distinct from that of most of the other species.

The dorsal cup is relatively low, scarcely higher than the tegmen, with a shallow concavity at the bottom leading to a small basal pit. Plates low convex, with smooth surface, and a sharp, abruptly rising median ridge (not well preserved in Wachsmuth and Springer's specimen) upon the radial series extending to the arm bases. Tegmen rather high, composed of large, smooth plates, with broad and shallow interambulacral depressions. Arms 10. It is large-sized species, typical specimens being about 24 mm. high, and 36 mm. wide, and average height to width about 1:1.4.

Horizon and locality.—Onondaga limestone: Schoharie and elsewhere in New York.

DOLATOCRINUS MARSHI Lyon.

Plate 5, fig. 14.

Dolatocrinus marshi Lyon, Trans. Amer. Philos. Soc., vol. 13, 1869, p. 461, pl. 27, figs. *n*, *n'*, *n*.²—Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 12, not pl. 1, fig. 8=*D. grandis*.—Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 312, pl. 26, figs. 1*a–d*.—Rowley in Greene, 1903, p. 159 (not pl. 47, figs. 7, 8=*D. grandis*).

Of the type of *D. speciosus*, with a similar high, abruptly rising radial ridge continuous to the arm bases, but with rather more angular sides, higher tegmen having a few small scattering tubercles, and a strong dorsal ornament by fine radiating striae. It is on an average of smaller size, and height to width is about 1:1.3. The entire facies of this form bears a strong resemblance to that of the New York species, the figured specimen of which might conceivably be a much eroded specimen of this. If a well-preserved New York specimen showed distinct radiating striae upon the radial and interbrachial plates, I should not know how to separate the species. The long redescription and figure of this species by Miller and Gurley were based upon a small specimen of *D. grandis*, and are erroneous and misleading in every particular; Rowley followed their example, but afterwards made a new species for his specimen. Those of Wachsmuth and Springer were made from Lyon's very perfect type specimen, now in my possession.

This species was for a long time extremely rare, but I obtained in recent years a number of additional good specimens which confirm the type, but indicate some variation in size by way of increase to a maximum of 35 mm. high by 50 mm. wide, one-half larger than the usual size. From these it is seen that secundibrachs to the number of three are incorporated, followed by one or more biserial pairs, producing four to six conspicuous pinnule openings to the interbrachial spaces, and giving an appearance at the arm bases analogous to that of *D. grandis*, by which Miller and Gurley were probably misled.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS GRANDIS Miller and Gurley.

Plate 7, figs. 1–8; plate 9, fig. 5; plate 10, fig. 2.

Cacabocrinites sculptus Troost MS., Proc. Amer. Assn. Adv. Sci., 1850 (read 1849), p. 60; Bull. 64, U. S. Nat. Mus., 1909, p. 55.

Dolatocrinus grandis Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 14, pl. 2, figs. 4–6; pl. 1, fig. 8 (as *D. marshi*).—Wood, Bull. 64, U. S. Nat. Mus., 1909, p. 55, pl. 12, fig. 2.

Dolatocrinus excavatus Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 321, pls. 25, fig. 1, and 26, figs. 7, 8.—Rowley in Greene, 1903, pp. 134, 145, 191.

Dolatocrinus grandis, var. *incarinatus* Rowley in Greene, 1903, p. 112, pl. 35, figs. 1–3.

Dolatocrinus marshi Rowley in Greene, 1903, p. 159, pl. 47, figs. 7, 8.

Dolatocrinus fossatus Rowley in Greene, vol. 2, 1906, p. 7, pl. 3, figs. 1–3.

This splendid species is most appropriately named, not only on account of its large size, but of the decisive way in which it stands out among all species of the genus, so perfectly distinct that there is no other with which it could be confused. The specimen upon which it was described, while excellent in some respects, was not in condition to exhibit all the characters, especially those of the base, and it is therefore necessary to give some further illustrations.

The species is remarkable for the extent to which the base is excavated and indented by the huge column facet. While the calyx wall curves inward to form a broad concavity on the dorsal side, within this there is sunken a large and very deep pentagonal pit involving the whole of the radials, the upper margins of which form the angular edge of the pit, and at the bottom of which, at about the level of the arms, lie the rather small basals, buried under at least half an inch of column when in place.

It is also remarkable for the manner in which the two large biserial arms of the ray are incorporated in the calyx, coincident with the fixation of pinnules, so as to produce an unprecedented number of pinnule openings directly from the calyx before the arms become free, there being as many as 8 to 12 in some interrays. The number as observed in practice often depends upon the depth to which the arm is broken away in the fossil.

The species also differs from all others in having the first interbrachial 10-sided, so that the upper face is angular and supports two large plates in the second range instead of a single one, as is the case normally in all other species of the genus so far as known. These two plates succeeding iBr_1 were formerly supposed to be interbrachials, but with our present understanding of the mode of succession of the incorporated pinnules, it is clear that they are the first pinnulars of the fixed pinnules which lead from the first secundibrachs, and that this species has actually no interbrachials beyond the first. In the exceptional cases where the iBr_1 is truncate, the

single plate which follows it in turn supports the two large pinnulars. This character of two so-called second interbrachials is thoroughly constant for the species, and is one by which it is readily identified from a fragment, the very few exceptions being clearly sporadic. I have 32 specimens with the plates of the dorsal side preserved, and in only three of them is there a reduction (in some interrays, never in all) of these plates to the single one of other species, one of them being the specimen used by Wachsmuth and Springer in describing their species, *D. excavatus*, which must now go into synonymy. The abnormal specimen from which the description was made was also exceptional in having keellike ridges somewhat similar to those of *D. spinosus*, from a specimen of which the basal cavity was drawn, that of the type being filled with matrix; so the figure as to this part is incorrect. Both specimens were poor, neither of them typical of the species to which it belonged. Miller and Gurley anticipated the publication with their two fine species, which happily obviates any confusion now, although some authors persisted in using the name *D. excavatus*, notwithstanding I had privately informed them that the species could not stand.

The shallow, broader concavity outside of the basal pit usually involves part of the axillary primibrach. The radial series from the edge of the pit slope gradually from their margin to the middle, forming a broad, rounded, sometimes angular, median ridge; and exceptionally in well preserved specimens the two primibrachs are raised into a broad conical node radiately grooved, or rarely into a keellike ridge as in *D. spinosus*. The surface is more or less sharply sculptured with numerous somewhat sinuous lines and wrinkles. There is considerable variation in this ornament, but it is wholly subordinate to the dominant characters of the species.

The tegmen is broadly convex, with a slight overhang at the margin, composed of more or less rugose plates, mostly large; but the interambulacral areas are occupied by transverse belts of narrow, elongate, triangular plates, between the lower, thin apexes of which the numerous pinnule openings emerge. Such long tegmen plates are a feature of all those species having several openings to the interray, and those with the larger number have a slightly overhanging roof. The relation of the pores, as already discussed, to the fixed pinnules which lead to them is well shown in the lateral views given on plate 7, figures 2, 4, 5.

D. grandis is a good illustration of the small importance to be attached to minor variations occurring in a form having a few strong and dominant specific characters; modifications of surface structure, for example, which might be utilized toward the differentiation of forms less definitely fixed, may here be wholly disregarded.

In size *D. grandis* is typically a very large species, maximum specimens attaining 35 mm. in height and 60 mm. in width, the average ratio of height to width being about as 1 to 1.6. But few approach a minimum of 20 mm. wide; a specimen of that size, abnormal, like the three above mentioned, in having a single iBr in the second range of some interrays, was mistaken by Miller and Gurley for *D. marshi*, and figured as such in their endeavor to improve upon Lyon's original description of the species. Misled by their misidentification, Rowley figured a specimen of this species in 1903 as *D. marshi*, but afterwards in 1906 decided to make a new species of it, namely, *D. fossatus*. His *D. excavatus*, var. *incarinatus* was separated because lacking a keeled radial ridge, and having a high tegmen, both being individual variations observable in a large series of specimens.

As early as 1849 this species was recognized by the pioneer western geologist and paleontologist, Gerard Troost, of Tennessee, who prepared an elaborate description and good figure of it under the name *Cacabocrinites sculptus*, announced by Prof. Louis Agassiz at the meeting of the American Association for the Advancement of Science for that year. This would have been the type of the genus but for the long delay in publication, by which Troost's priority as to this and many other well-known crinoids was lost.[12]

Miller and Gurley[13] give the horizon of *D. grandis* as Hamilton; but it is well known to all the collectors that the specimens of this species occur only in the Onondaga formation (usually labeled "Upper Helderberg"), below the hydraulic beds which constitute the recognized boundary in that locality. Mr. Greene in a letter to me of November 9, 1903, in reply to an inquiry touching the horizon of this and other species, informed me that he furnished Mr. Gurley the types of *D. grandis* and *D. spinosus*, and that both came from the "Upper Helderburg" at Louisville.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS SPINOSUS Miller and Gurley.

Plate 8, figs. 1–7; plate 10, fig. 1.

Dolatocrinus spinosus Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 8, pl. 1, fig. 4.—Rowley in Greene, 1903, p. 164, pl. 48, fig. 4.
Dolatocrinus curriei Rowley in Greene, 1903, p. 143, pl. 42, figs. 1–6.

This is one of the two leading species of the Onondaga beds at Louisville (although erroneously stated by its authors to be from the Hamilton). Miller and Gurley had a poor specimen, in which the surface sculpture was not preserved; but there was enough other-

[12] See the account of this by Miss Wood, Bull. 64, U. S. National Museum, 1909, pp. 1–7.
[13] Bull. 4, p. 16.

wise to enable them to give a recognizable definition from which the species can be identified beyond any question. With about 50 specimens in my own collection for comparison, many of them very well preserved, the essential characters are clearly evident, as the new figures show.

As in the case of *D. grandis*, this is typically a large-sized species, 33 of the specimens being from 40 to 55 mm. in width, and 8 from 30 mm. down to a minimum of 15 mm. wide, the remainder being intermediate; the average height to width of the calyx is about 1: 1.65, and the height of the dorsal cup is usually more than half that of the calyx. Below the arm openings the calyx is depressed hemispheroidal, shallowly concave below, with column facet abruptly sunk, involving only the basals. The first interbrachial is a very large plate, 11-sided from the abutting of IIIBr due to the second bifurcation in the ray, giving 4 arms to the ray contrasted with the 2 in *D. grandis;* this plate is truncate above, supporting one large median second interbrachial, as usual in the genus, with the sole exception of *D. grandis.*

The surface ornament in general consists of fine radiating lines, producing combinations which take the form of included triangles, and sometimes crossed by others, causing a pitted appearance. The one conspicuous feature of the sculpture is a strong, keel-like ridge along the radial series, which however is always confined to the radials and primibrachs. This keeled protuberance varies in shape from a fairly strong rounded ridge to a very high, knifelike edge; but it never passes along the ray beyond the primibrachs.

The tegmen is moderately convex, sometimes more or less conical, broadly but not deeply lobed, and surmounted with strong spines above the ambulacral series and around the base of the tube. Pinnule openings four to the interray, the outer pair often broken away; and two, sometimes four, in the spaces within the ray; not so prominent as in *D. grandis.*

With such a large number of specimens in hand it is interesting to see how true to type they run. Out of 21 specimens having the tegmen intact, all except 3 have strong spines, and in these, although rather weak, the projections are nevertheless pointed spines. Of the 20 specimens in which the arms can be counted, the only departure from the normal 20 arms is seen in two specimens which lack an arm in two rays and in one ray, respectively.

Rowley's *D. curriei* is merely a typical specimen with the surface ornament preserved, which was lacking in the type.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS LAMELLOSUS Hall.

Cacabocrinus lamellosus HALL, Fifteenth Report, New York State Cab., 1862, p. 141

This species has never been figured. What purports to be the type specimen in the American Museum of Natural History has only the dorsal parts preserved. It is a very large, crushed specimen about 55 mm. wide, with plate arrangement similar to that of *D. spinosus*. Although recorded by Hall as from western New York, without definite locality, this specimen, lying with some others from Louisville, strongly resembles them in appearance, and may be from the same locality. It may be identical with *spinosus*, and if so would take priority; but inasmuch as we know nothing of the tegmen, in which one of the important characters of that species occurs, the evidence is insufficient for a decision, and the younger name will have to stand, leaving the other one in doubt.

Horizon and locality.—? Hamilton shales of western New York.

DOLATOCRINUS INSUETUS Rowley.

Plate 8, fig. 8.

Dolatocrinus insuetus ROWLEY in Greene, vol. 2, 1906, p. 8, pl. 3, fig. 4.
Dolatocrinus excavatus ROWLEY in Greene, 1903, p. 191, pl. 57, fig. 17.

Of the type of *D. spinosus*, but the keellike ridges traverse the entire radial series to the arm bases; and the tegmen, instead of strong spines, has usually only a few sharp tubercles. It is a good species, definitely marked, and I am glad to be able to confirm Professor Rowley's description by four fine specimens in which the correlation of the above noted characters is fairly constant.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS MAJOR Wachsmuth and Springer.

Plate 9, figs. 1, 2.

Dolatocrinus major WACHSMUTH and SPRINGER, North American Crinoidea Camerata, 1897, p. 312, pl. 25, fig. 5.

This is another very striking species of the Onondaga, hitherto but little known, which is marked by some decisive characters. When described, the type was the only specimen known, and that one lacked the tegmen; but the subsequent acquisition of eight additional specimens has confirmed the diagnosis, while also showing a considerable range of variation within a strong specific type. The position and arrangement of the pinnule openings resemble those of *D. grandis*, reduced in number owing to the doubling of the arms, and there is also a sporadic appearance of 2 plates in the second interbrachial range; but otherwise there is no close relation to that species.

This form is usually of very large size, flattened specimens ranging from 50 to 75 mm. in width, but even a small one of only 40 mm.

diameter shows no material departure from the typical characters. The perfectly smooth surface, without sculpturing or any other marking except a small node or spine on the first (sometimes second) primibrach, which exceptionally also develops into a keellike ridge as in *D. spinosus;* and the peculiar cordate shape of the first interbrachial, with its usually wide distal margin for the support of the very large second plate (exceptionally angular and supporting two plates as in *D. grandis*); are characters which readily differentiate the species from all others.

A somewhat crushed calyx with part of the smooth tegmen intact shows the arrangement of the pinnule openings, four or six to each interspace between the 20 arms; it shows that the general form of the calyx was broad and low, somewhat constricted below the arms, with a truncate or broadly curving base containing a relatively small basal pit. In this the basals are seen to be more or less obsolete, encroached upon and much of their substance resorbed and replaced by the large stem-lumen, analogous to the case of *Hadrocrinus.* In three specimens the nodes on the radials have enlarged into high, keeled ridges, and in one they are produced into sharp spines—variations which are immaterial in view of the strong dominant characters of the species.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS EXSTANS, new species.

Plate 10, figs. 8, 9.

In this species we have a complete departure from the usual habitus of the genus in the presence of a strongly protuberant base, instead of the usual concave or flat condition. It is proposed upon the evidence of eight specimens, which were found by the late George K. Greene, in the Onondaga formation at the Falls of the Ohio, near Louisville. They were obtained during a season of low water, all from the same layer and rather near together, the form being entirely new in the experience of the collectors of that locality. The specimens are all more or less crushed and imperfect, but indicate a calyx of large size—probably 65 or 70 mm. in diameter—and having at least 6 arms to the ray, or 30 (perhaps more) in all. The plates of the dorsal cup have usually a conical central elevation. Correlated with the protuberant base is the presence in the tegmen of long, sharp spines, some of them 25 mm. in length. The interbrachials are of the typical form for the genus, with an occasional irregularity—the large plate of the first range being sometimes 11-sided on account of contact with tertibrachs.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS MULTIBRACHIATUS Rowley.

Plate 9, figs. 3, 4.

Dolatocrinus multibrachiatus ROWLEY in Greene, 1903, p. 141, pl. 41, fig. 7.

Founded on a specimen having a calyx similar to that of *D. spinosus*, but with an additional bifurcation in the rays, giving 40 arms. I am able to confirm it by seven specimens of similar form having one or more rays preserved, all of which have six or eight arms to the ray. I have figured one of these, which is badly crushed, but shows the surface characters better than the type, and another clearly showing the numerous arms.

Horizon and locality.—Onondaga (Jeffersonville) limestone: Louisville, Kentucky, and vicinity.

HAMILTON SPECIES.

[Valid species in italics; synonyms in roman.]

With 10 arms.
- Medium to large size.
  - Calyx wide and low; ornament with sharp radiating striae. *D. liratus.*
    —var. multilira.
  - Calyx higher, ornament with interrupted lines or pustules. *D. glyptus.*
    —var. intermedius.
  - Calyx, low, basin-shaped, with small basal pit; ornament variable, strong nodes or fine striae predominating..... *D. asperatus.*
    —marshi, var. hamiltonensis.
- Small, subglobose to oblate spheroidal.
  - Strong central nodes, with coarse radiating striae; ridges forming rim around basal pit.
    - Calyx rather high..... *D. bulbaceus.*
      —pulchellus.
      —aspratilis.
      subaculeatus.
    - Calyx broader, ornament obscure..... *D. argutus.*

With 10 to 20 arms.
- Small to medium size.
  - Calyx decanter-shaped, truncate and broadly concave below, basal cavity bordered by prominent pentagonal rim. Radial ridges and nodes inconspicuous; radiating striae sharp, both fine and coarse.
    - Tegmen high, conical, smooth; pinnule openings conspicuous. Tegmen not lobed. Arms about 15..... *D. stellifer.*
      —hammelli.
      —laguncula.
      —aplatus.
      —dissimilaris.
      —neglectus.
    - Tegmen lobed. Arms 15..... *D. triadactylus.*

With 10 to 20 arms—Continued.
Small to medium size—Continued.
Calyx large, subcylindrical; base broadly concave, without pentagonal rim. All plates of cup tumid, rugose, radiately furrowed or wrinkled, sloping from margin to center. Tegmen subconical, smooth. Pinnule openings conspicuous.
Tegmen somewhat lobed.
Arms 15 to 20..... *D. amplus.*
—vasculum.
—peculiaris.
—lyoni Wachsmuth and Springer.
—pernodosus.
—wachsmuthi.
Tegmen less lobed. Wrinkles on cup plates rather irregular. Arms 20, in nearly continuous ring..... *D. costatus.*
Calyx of medium size, more or less rotund above; base truncate, with narrow pit.
Radiating striae strong, those on iBr and radials forming a conspicuous star around the basal pit.
Tegmen not lobed; low, convex, rugose. Pinnule openings conspicuous. Arms normally 15..... *D. asterias.*
Radiating striae sharp, forming triangles, but not sharply defined star; ridges not prominent.
Tegmen rugose, broadly lobed. Pinnule openings obscure. Arms 20..... *D. incisus*, new species.
Calyx small to medium size; bowl-shaped, hemisperoidal, not constricted below arms; sides curving evenly upward from narrow base. Tegmen low. Pinnule openings not conspicuous. Arms 15 to 20.
Medium size; strong nodes radiately arranged, or interrupted ridges on plates, without fine striae..... *D. venustus.*
—aureatus.
—lyoni Miller and Gurley.
—corbuliferus.
Fine striae forming triangles.
Tegmen strongly lobed, and more or less spinous..... *D. bellarugosus.*
—coelatus.
—arrosus.
—var. cognatus.
—depressus.
Small; radial ridges high and sharp, with fine striae. Arms mostly about 20..... *D. exornatus.*
—dispar.
Insufficiently known. Arms 15..... *D. canadensis.*
Calyx large to medium size. Bursiform, constricted below the arms; base truncate, broad, flat, or shallow concave; tegmen more or less lobed; pinnule openings often inconspicuous, usually 2 to each arm base, may be 4 to the interray.

With 10 to 20 arms—Continued.
Calyx large to medium size, etc.—Continued.
Ridges on radial series more or less continuous; central nodes on RR and iBr not prominent, or absent.
Surface ornament chiefly by rows or clusters of pustules or wrinkles more or less radiately arranged.
Very large and massive; surface coarsely wrinkled..... *D. magnificus.*
Less massive; calyx broad; radial ridges low, rounded, not enlarging at the centers; ornament by sinuous radiating lines.
Tegmen low and broadly lobed..... *D. corporosus.*
—var. decoratus.
—welleri.
Surface ornament by distinct radiating striae tending to form geometrical figures, more or less combined with scattered pustules.
Calyx broad and low.
Tegmen low, smooth, obscurely lobed, plates indistinct..... *D. indianensis.*
—preciosus.
Tegmen rugose, distinctly lobed, plates well defined, with small nodes or pustules.... *D. greeni.*
—corporosus, var. concinnus.
Calyx high.
Tegmen ventricose or high conical, strongly lobed, more or less covered with small nodes or pustules..... *D. lineolatus.*
—sacculus.
—salebrosus.
—charlestownensis.
—cistula.
—asper.
—eicosidactylus.
—springeri.
Ridges on radial series more or less discontinuous; nodes on radials and iBr prominent.
Surface ornament by radiating striae, usually distinct, forming geometrical figures.
Tegmen ventricose, lobed, with more or less small scattered spines or sharp nodes..... *D. belladus.*
—basilicus.
—noduliferus.
Tegmen flatter, but little lobed, and without nodes or spines..... *D. nodosus.*
—tuberculatus.
—multinodosus.
—elegantulus.
Tegmen lobed, with strong nail-head spines.... *D. fungiferus.*

As of the 62 species and varieties described from the Hamilton over 60 per cent are considered to be synonyms, it will be convenient to treat them by groups, following the arrangement in the foregoing key.

Form I. **LIRATUS** group.

Ten-armed; medium to large size.

DOLATOCRINUS LIRATUS Hall.

Plate 10, figs. 10, 11.

Cacabocrinus liratus Hall, Fifteenth Rep. New York State Cab., 1862, p. 139.
Dolatocrinus liratus Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 319, pl. 26, fig. 3.
Dolatocrinus liratus, var. *multilira* Hall, Fifteenth Rep. New York State Cab., 1862, p. 139.

Horizon and locality.—Hamilton shales: near Bellona, New York.

DOLATOCRINUS GLYPTUS Hall.

Cacabocrinus glyptus Hall, Fifteenth Rep. New York State Cab., 1862, p. 140.
Dolatocrinus glyptus Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 317, pl. 26, figs. 2*a*, *b*.
Dolatocrinus glyptus, var. *intermedius* Hall, Fifteenth Rep. New York State Cab., p. 141.

Ten-armed species of medium to large size, and strongly ornamented, the former with sharp radiating striae and the latter with interrupted lines or pustules; in the former the calyx is wider and lower than in the latter. The two species and varieties were not illustrated by Hall, but figures were given along with the redescription of them by Wachsmuth and Springer, and I have figured two typical specimens of *liratus*. Except for the difference in number of primibrachs, it would be difficult to distinguish this species from *Stereocrinus triangulatus* of the Michigan area. I have not the material for a critical comparison of these forms, which will be done later on by the New York State museum, and pending that I list the varieties as synonyms under the respective species, as was done by Wachsmuth and Springer. An extremely abnormal specimen of this type in the museum at Albany shows a single branching arm, which is evidently sporadic.

Horizon and locality.—Hamilton shale: Western New York.

DOLATOCRINUS ASPERATUS Miller and Gurley.

Plate 6, figs. 5–12.

Dolatocrinus ornatus, var. *asperatus* Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 15, pl. 3, figs. 4–6.
D. marshi, var. *hamiltonensis* Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 314, pl. 25, figs. 2*a*, *b*.

As a hold-over from the Onondaga, this form became subject to some extreme variations in surface characters, such as have been relied upon with confidence by authors in their descriptions, and some of which I am attempting to utilize further on in this paper to assist in holding a number of described species which probably

should all be dumped into synonymy. The earlier species is exceedingly well marked by its general curvature, small basal pit, low and strongly lobed tegmen covered with small tubercles, projecting lip above the interrays, and uniformly 10 arms. All these features the Hamilton forms have, so that one is struck by the resemblance at the first glance, despite the difference in size, and can not help feeling that this is a good example of the breaking up of specific lines incident to the approaching extinction of the group. The specimens are mostly of considerably larger size than those of the Onondaga species, and along with this the great variability in surface markings may be taken as a character upon which to call Miller and Gurley's variety a species. There are six good specimens besides the type, and they include ornament by fine striate lines, wrinkles, tubercles, or pits, with median radial ridge low and rounded, or concentrating in strong separate nodes on the radials and primary brachials, or extending keel-like and sharp to the arms. The last form covers Wachsmuth and Springer's *D. marshi*, var. *hamiltonensis*, which in the leading characters resembles this species more than the one with which it was associated. In addition to Miller and Gurley's type, I have figured four specimens of this form as an object lesson upon surface ornament in this genus.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

Form 2. BULBACEUS group.

Ten-armed; small, subglobose to oblate spheroidal.

DOLATOCRINUS BULBACEUS Miller and Gurley.

Plate 11, figs. 1–3.

Dolatocrinus bulbaceus Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 22, pl. 2, figs. 13–15.

Dolatocrinus pulchellus Miller and Gurley, Bull. 6, p. 55, pl. 5, figs. 13–15.—Rowley in Greene, 1903, p. 109, pl. 33, figs. 16–18.

Dolatocrinus aspratilis Miller and Gurley, Bull. 9, 1896, p. 49, pl. 3, figs. 16–18.

Dolatocrinus subaculeatus Whiteaves, Contr. Canad. Pal., vol. 1, 1898, p. 369, pl. 6, figs. 6, 6*a*.

A small, subglobose form with subpentagonal outline, well described and figured by Miller and Gurley under the several specific names above cited. Typically it is marked by sharp central nodes on first interbrachials and radials, with a strong ridge connecting the latter and forming the prominent rim of a broad pentagonal basal pit; the sculpturing may vary from sharp to obscure, and the general form from subglobose to oblate spheroidal. Arms 10. A well-defined type and abundant.

Out of 45 specimens in my collection, all of which in other respects are strictly conformable to the type, a single one sporadically has an extra arm in one ray, giving the 11 arms on which Miller and Gurley's synonym *aspratilis* was formed; along with the types in the Gurley collection are about 20 normal specimens of *bulbaceus;* and these two exceptional specimens are in every other character perfect examples of the species thus so numerously found. Two other of my specimens have an extra plate in the second interbrachial range in one area, a variation on which mainly *D. argutus* was described. The figured type of *D. bulbaceus* is incorrectly drawn; it is an abnormal specimen, having the posterior interradius irregular, with two plates in the second range like the two specimens in my collection above mentioned; it is of maximum size among specimens of this type, but with it in the Gurley collection as cotypes not figured are two smaller specimens of about average size—namely, 12 mm. high by 15 mm. wide. *D. aspratilis* is almost a counterpart of these two specimens; and I have figured a normal specimen from my collection.

This was a wide-ranging form, and occurs in the Hamilton of Thedford, Ontario, as *D. subaculeatus* of Whiteaves, which can not be distinguished from an average specimen of *bulbaceus.*

The authors say that *D. bulbaceus* has no "ovarian pores," and on their supposed absence chiefly proposed their second species, *D. pulchellus;* but the pinnule openings are present in the three types and in all well-preserved specimens; they are always close under the arm base, not in the open space between, one to each arm on the outside of the dichotom and rarely visible on the inside, as the arm usually becomes free after the first secondibrach. They also note for *pulchellus* a "difference in general form and surface ornament." The type of *D. pulchellus* is a relatively lower and wider form than that of *bulbaceus,* the ratio of height to width in the types of the several species being: *bulbaceus,* 1:1.25; *aspratilis,* 1:1.2; *pulchellus,* 1:1.5. A few specimens like the latter may be selected out of the general lot, but there would be every gradation between them and the others, all conforming strictly to the type in other respects. Relative sharpness or obscurity of the ornament proves nothing, all being of the same characteristic type, and the difference in prominence of sculpturing not being correlated with other characters. Professor Rowley, when figuring a specimen under the name *pulchellus,* says he has little doubt "that *D. bulbaceus, D. pulchellus, D. argutus,* and *D. aspratilis* are one and the same species."

Horizon and locality.—Hamilton limestone: Louisville, Kentucky and vicinity; Thedford, Ontario.

DOLATOCRINUS ARGUTUS Miller and Gurley.

Plate 11, figs. 4, 5.

Dolatocrinus argutus Miller and Gurley, Bull. 8, Ill. St. Mus., 1896, p. 41, pl. 3, figs. 4–6.

I have listed this species separately, although perhaps only a variant of the preceding. It has a little different aspect, being less globular and wider in proportion to height than typical specimens, and these characters being correlated with a shallower basal cavity, lower tegmen, less angular contour, and a decidedly smoother surface.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

From 3. STELLIFER group.

With about 15 arms. Decanter-shaped, with broadly concave base and smooth tegmen.

DOLATOCRIUNS STELLIFER Miller and Gurley.

Plate 11, figs. 6–8.

Dolatocrinus stellifer Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 20, pl. 2, figs. 10–12.

Dolatocrinus hammelli Miller and Gurley, Bull. 6, 1895, p. 52, pl. 5, figs. 4–6.

Dolatocrinus aplatus Miller and Gurley, Bull. 8, 1896, p. 48, pl. 3, figs. 16–18; Bull. 9, pl. 3, figs. 13–15.—Rowley in Greene, 1903, p. 136, pl. 39, figs. 6–8.

Dolatocrinus laguncula Miller and Gurley, Bull. 9, 1896, p. 51, pl. 3, figs. 19–21.

Dolatocrinus dissimilaris Miller and Gurley, Bull. 9, 1896, p. 54, pl. 3, figs. 25–27.

Dolatocrinus neglectus Miller and Gurley, Bull. 12, 1897, p. 37, pl. 2, figs. 27–29.

A group of synonyms representing a single well-defined form, of a thoroughly distinct facies, readily recognized from fragmentary specimens, and differing from one another only in immaterial and inconstant details.

Calyx decanter-shaped, with dorsal cup low, deeply and broadly concave at the base, the concavity extending to the middle of the first interbrachial; the tegmen rising in a high neck, which passes gradually into the subcentral anal tube. Measuring to the level where the tube begins to be defined, the proportionate height to width is about 1:1.6 in the types of all the species. Radial ridges are small and inconspicuous, and on each side of them, connecting with the interbrachials, the plates are closely, deeply, and radiately striated, forming geometrical figures. This sculpturing varies from coarse (single) to fine (doubled) striae, without any relation to other characters, the latter style being rather the most common; in the four type specimens of *D. aplatus* two have fine striae and two coarse. A very distinct ridge connecting the centers of the radials forms a

pentagonal figure within the general basal concavity that is a conspicuous feature of the ornamentation.

The tegmen is rather evenly convex to the base of the tube, and its perfectly smooth and even surface, combined with the decanter shape, produces a habitus that is highly distinctive. This characteristic appearance is enhanced by the prominence of the pinnule openings, which are large curved slits, conspicuously placed in the open spaces between the arms, one at each side of every arm base, and frequently two more in the interrays. The habitus thus indicated is uniform among the type specimens of the several species and also throughout a series of good specimens additional to the types.

The distinction chiefly relied upon by the authors in the descrip- of these species is the number of arms, as to the sufficiency of which they are quite frank. Under *D. laguncula* [14] they say:

> In surface ornamentation and general form it resembles *D. hammelli*, but that species has 16 arm openings, while this has only 14, which will readily distinguish the species.

And under *D. dissimilaris* [15]:

> In general form it resembles *D. aplatus*, but that species has 15 arms, while this has 13, so the arm formula alone will distinguish them.

I have in hand for the study of this form the 7 figured types and 5 cotypes labeled with them, 9 other specimens from the Gurley collection, and 16 from my own, making 37 in all. The range of variation in arms among them is from 11 to 17 in number, distributed as follows: With 11 arms, 1; with 13 arms, 7; with 14 arms, 5; with 15 arms, 20; with 16 arms, 3; with 17 arms, 1.

Thus more than half the specimens have 15 arms, and 95 per cent of them have that number within one or two more or less; which indicates that 15 is the normal number—3 arms to the ray, as it is almost without exception in the closely related *D. triadactylus* from Michigan—the small deviations from the normal being due to sporadic increase or diminution irregularly in one or two rays.

I have also examined the specimens with reference to the so-called "ovarian apertures," which are so strongly featured in the descriptions. As stated above, there are always a pair of them at each arm base in this form, and frequently an additional pair between the main ray divisions; but these differences are not uniform for the species as described. For example, in *D. hammelli*, the "16-armed species," the description says there are two apertures in each interradial area and two separating the arms in each of the five rays, giving "20 of these apertures;" yet one of the specimens selected by the authors as a cotype, and also a 16-armed specimen of my own, have four apertures between the rays, or about 40 in all. *D. aplatus*, the

[14] Bull. 9, p. 52. [15] Idem, p. 55.

"15-armed species," is described with "four ovarian slits between each (*sic*) radial series, and two between each (*sic*) of the ambulacral openings, which gives to this species 40 ovarian apertures;" but among the cotypes selected by the authors are three specimens with only two openings either between the rays or their divisions, and among 16 other specimens with 15 arms, 11 have two and four openings, and four have only two to each interval. The same thing applies to *D. laguncula*, the "14-armed species," which among five specimens has two with two and four openings, and three with only two. So if the species were to be arranged according to this character it would throw together forms with 11, 13, 14, 15, and 16 arms in one species, and forms with 13, 14, 15, 16, and 17 arms in another. As to these openings, the number observed depends somewhat upon the preservation of the specimen and the level at which the arms are detached; two of the openings in the interrays are well exposed in the median part, and always very plain, but the other two often lie close under the arm bases, and if the first pair of arm brachials are broken off these openings may not be seen. It is probable that there were normally four openings to the interrays, two of which may not always be observable for the reason stated.

The species is of medium size, ranging from about 12 to 20 mm. height of calyx to where the tube becomes defined, and 18 to 32 mm. in greatest width, the average height to width being about as 1 : 1.6.

Horizon and locality.—Hamilton (Sellersburg) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS TRIADACTYLUS Barris.

Plate 11, figs. 9, 10.

Dolatocrinus triadactylus Barris, Proc. Acad. Sci., Davenport, Iowa, vol. 4, 1884, p. 100, pl. 2, figs. 5–7.—Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 316, pl. 26, figs. 4*a–d*.

This form, from the Traverse beds of the Michigan Hamilton, belongs to the *stellifer* group, having the same excavate base, high, smooth tegmen, and the same type of sculpturing, including both fine and coarse striae, with a pentagonal rim bounding the basal cavity. It differs in having a strongly lobed tegmen. The 15 arms are constant in 23 out of 29 specimens, four others having 14, and two 16, all being from the same vicinity. It ranges in size from 7 to 23 mm. high, and 8 to 28 mm. wide. Especially among the smaller specimens, the calyx is relatively higher than in the Louisville form, so that the average height to width is here about 1 : 1.25.

Horizon and locality.—Hamilton (Traverse) shales: Alpena, Michigan.

Form 4. AMPLUS group.

Large, with broadly concave base; calyx plates tumid and rugose. Arms 15 to 20.

DOLATOCRINUS AMPLUS Miller and Gurley.

Plate 11, figs. 11–17; plate 12, figs. 14, 15.

Dolatocrinus amplus Miller and Gurley, Bull. 5, Ill. St. Mus., 1894, p. 45, pl. 4, figs. 6–8.—Rowley in Greene, 1903, p. 154, pl. 45, figs. 10–12.
Dolatocrinus vasculum Miller and Gurley, Bull. 6, 1895, p. 53, pl. 5, figs. 7–9.
Dolatocrinus peculiaris Miller and Gurley, Bull. 9, 1896, p. 55, pl. 3, figs. 28–30.
Dolatocrinus lyoni Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 314, pl. 25, figs. 6*a–d*.
Dolatocrinus pernodosus Rowley in Greene, 1903, p. 113, pl. 35, figs. 4–6.
Dolatocrinus wachsmuthi Wood, Smithson. Misc. Coll., vol. 47, 1904, p. 77.

A sharply defined form, well described by the authors under *D. amplus*, with which they should have been content, without encumbering the literature with useless synonyms, based wholly on variation in the number of arms from 17 to 20. Wachsmuth and Springer described a typical specimen with 15 arms, which, according to Miller and Gurley's major criterion, should be a good species. Rowley added another with 17, because differently grouped; and from my material now in hand I could swell the list with a new species of 16 arms. Miss Wood contributed an additional name to replace the preoccupied species of Wachsmuth and Springer.

All these names and numbers stand for a single species, of a type so distinctive in plan of sculpturing that it may be recognized from a fragment containing a few plates of the dorsal cup. Instead of being marked by radial ridges, striae, or more or less prominent central nodes, all the plates are tumid or subspinous, radiately wrinkled or furrowed toward the margins, to which they slope from a a rounded or pointed center. The calyx is broadly truncate at about the level of the second primibrach, from which it curves inward to a broad concavity, involving the radials and part of the first interbrachials to about half the depth of the dorsal cup. It is subcylindrical from the level of the base up, and sometimes slightly constricted below the arms. Tegmen rather low, subconical, smooth, or finely pustulose; somewhat depressed or lobed in the interambulacral spaces. The pinnule openings are conspicuous in the form of long slits, two to each arm, and frequently four in the interrays. The two outside ones are located well under the edge of the arm base, and are often broken away.

The species is of large size, ranging from 20 to 35 mm. high and 30 to 50 mm. wide, the relative height to width averaging about 1:1.3.

In the broadly concave base, smooth tegmen, and prominent pinnule openings, this form is nearest to *D. stellifer*. Besides the

three types in the Gurley collection, I have eight good specimens, showing a range of from 15 to 20 arms, distributed as follows: Four with 15 arms, one with 17, one with 18, and five with 20. The characters otherwise are uniform in every essential particular. The pictures of surface ornament in Miller and Gurley's figures are not always to be depended on, and those given of this form show more difference among themselves than actually exists.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

DOLATOCRINUS COSTATUS Wood.

Plate 12, figs. 1, 2, 3.

Dolatocrinus costatus Wood, Smithsonian Miscellaneous Collections, vol. 47, 1904, p. 70, pl. 16, figs, 6, 6*a*.

A good representative of the *amplus* group, from the Traverse beds of Michigan. In addition to the type figured by Miss Wood, I have three other specimens, one larger and two smaller; all have 20 arms, except one, which has an extra arm in one ray. So the number, toward which there was a strong tendency in the Louisville area, is here well established at 4 to the ray. There is a difference, not very clearly definable, in the style of sculpturing, due to the strong wrinkles on the plates of the cup, being in *costatus* less regularly radiating: the tegmen plates are more distinctly outlined, and the arms more nearly in a continuous ring. Pinnule openings are very conspicuous—two and four between arms and four or six between the rays. The specimens range in size about as those of the Louisville form—from 20 to 35 mm. high and 30 to 50 mm. wide.

Horizon and locality.—Hamilton (Traverse) shales: Alpena, Michigan.

Form 5. ASTERIAS group.

More or less rotund, with sides nearly vertical, truncate base and small basal pit.

DOLATOCRINUS ASTERIAS Wood.

Plate 12, figs. 4–7.

Dolatocrinus asterias Wood, Smithsonian Miscellaneous Collections, vol. 47, 1904, p. 71, pl. 16, figs. 1, 1*a*.

A medium-sized species, but small specimens are found occasionally. Calyx broadly basin shaped, more or less round above; sides nearly vertical or slightly expanding upward, and base truncate, with small, pentagonal-rimmed basal pit. Radiating striae strong and coarse, those from the first interbrachials crossing the radials and forming a conspicuous star surrounding the basal pit. Tegmen low convex, not lobed, covered with rugose plates. Pinnule openings conspicuous—two to each arm base and three or four in the interrays. Arms 15, their openings directed obliquely upward.

The basal star is a most striking and constant character, by which the species is readily recognized from the base alone. I have 25 specimens, in all of which it is perfectly distinct. Among 13 specimens in which the arm openings are observable, 10 have 15 arms, and one each 13, 14, and 16. In size the specimens range from 18 to 25 mm. high and 25 to 32 mm. wide, with a few somewhat larger or smaller. The average height to width is about 1:1.35, the smaller specimens being relatively higher and the larger ones lower.

Horizon and locality.—Hamilton group: Alpena and Partridge Point, Michigan.

DOLATOCRINUS INCISUS, new species.

Plate 12, figs. 8–13.

Similar to *asterias*, with which it is associated, but with more broadly concave base, and without the strongly modeled basal star, although a stellate arrangement of triangles is apparent in some specimens. Radiating striae sharply incised, wrinkled, forming triangular figures, either single or enclosing others. Tegmen broadly lobed. Pinnule openings obscure, probably two to each arm base. Arms 20.

The type of sculpturing is similar to that of *Stereocrinus triangulatus*, and unlike that of other Michigan forms of this genus. I have seven specimens of this form, ranging in size from 10 to 23 mm. high and 16 to 36 mm. wide; six of them show all the arm openings, which are 20 without exception.

Two specimens are figured, to show the extremes of fine and coarse sculpturing of the same type.

Horizon and locality.—Hamilton (Traverse) shales: Alpena, Michigan.

Form 6. VENUSTUS group.

Calyx small to medium size, bowl-shaped, hemispheroidal, not constricted below the arms; sides curving evenly to arms from narrow base, not concave. Tegmen low. Pinnule openings inconspicuous—2, or perhaps only 1, to each arm base. Arms, 15 to 20.

This general description includes a group of six species by Miller and Gurley and one by Rowley, among which I have attempted to separate three definable forms. All are typically small species, having about the same general proportions, and ranging from 8 to 20 mm. high and 12 to 28 mm. wide, the average height to width being 1:1.5. I have 22 specimens besides the types of Miller and Gurley, minus that of *exornatus*, which with two other of their types was lost before the Gurley collection was received by the University of Chicago, and for which we must rely upon the figures and descriptions. The arms in these 28 specimens vary from 12 to 20, distributed as follows: with 12 arms, 1; with 13 arms, 2; with 15 arms, 3; with 16 arms, 6; with 17 arms, 8; with 18 arms, 1; with 19 arms, 4; with 20 arms, 3.

These numbers bear no relation to any other characters, but it will be noted that 90 per cent of the specimens have 15 arms or more, and 60 per cent of them have 15 with only one or two arms more or less; so the type for this form is 15 arms, with a tendency to increase toward 20. The grouping of the species hereunder is more or less artificial, and the definitions are lacking in decisive characters, depending altogether upon the surface markings.

DOLATOCRINUS VENUSTUS Miller and Gurley.

Plate 13, figs. 1–5; plate 15, fig. 8.

Dolatocrinus venustus Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 23, pl. 2, figs. 16–18.—Rowley in Greene, 1903, p. 160, pl. 47, figs. 9, 10.
Dolatocrinus aureatus Miller and Gurley, Bull. 4, 1894, p. 24, pl. 3, figs. 1–3.
Dolatocrinus lyoni Miller and Gurley, Bull. 9, 1896, p. 44, pl. 3, figs. 4–6.
Dolatocrinus corbuliferus Rowley, 1903, p. 151, pl. 44, figs. 13–15.

Interrupted ridges, coarse nodes or pustules. These surface characters are not so well shown by the original figures as by the new drawings here given, made upon a photographic basis directly from the type. More faulty still are the authors' figures of *venustus* in not showing the general hemispheric contour, which is missed completely in their side view (fig. 17). The description agrees with the type as it is designated in the Gurley collection. Some other specimens among the duplicates labeled with this name are of doubtful authenticity, but I have four good specimens that can be assigned to this species, including a very characteristic one from Michigan. The species attains a larger size than the other two, ranging from 12 to 23 mm. high and 20 to 38 mm. wide.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana and vicinity.

DOLATOCRINUS BELLARUGOSUS Miller and Gurley.

Plate 13, figs. 6–10.

Dolatocrinus bellarugosus Miller and Gurley, Bull. 8, Ill. St. Mus., 1896, p. 43, pl. 3, figs. 7–9.
Dolatocrinus coelatus Miller and Gurley, Bull. 8, Ill. St. Mus., 1896, p. 46, pl. 3, figs. 13–15.—Rowley in Greene, 1903, p. 165, pl. 48, figs. 10–12.
Dolatocrinus arrosus Miller and Gurley, Bull. 8, Ill. St. Mus., 1896, p. 52, pl. 3, figs. 22–24.—Rowley in Greene, 1903, p. 132, pl. 38, figs. 9, 10.
Dolatocrinus arrosus, var. *cognatus* Rowley in Greene, 1903, p. 137, pl. 39, figs. 12–14.

Base rather wider than in the last species. Ornament by radiating striae with strong median ridges, more or less interrupted, and rather prominent central nodes. Tegmen sharply lobed and more or less spinous. The first three of Miller and Gurley's types are essentially duplicates, with a difference of one arm; the others differ slightly in proportions. I have 10 specimens besides, varying in

arms from 13 to 20, but 80 per cent of them from 15 to 17; and in size from 12 to 16 mm. high, and 17 to 22 mm. wide.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana and vicinity.

DOLATOCRINUS EXORNATUS Miller and Gurley.

Plate 13, figs. 11, 12.

Dolatocrinus exornatus Miller and Gurley, Bull. 6, Ill. St. Mus., 1895, p. 54, pl. 5, figs. 8–10.
Dolatocrinus dispar Miller and Gurley, Bull. 9, 1896, p. 40, pl. 2, figs. 27–29.

Very small, with extremely fine striae; radial ridges high and sharp. The size is consistently small, being almost uniform at 8 mm. high and 12 mm. wide, and the tendency is to 20 arms. Out of seven specimens plus the types more than half have 19 to 20 arms, and all may have had about 20, as in this form the first bifurcation of the ray occurs very high up, and the next one is at the edge of the calyx, where the arms are becoming free, so that the second axillary is sometimes broken off and the full number of arms is not seen.

Comparison of the original description of this species with that of *D. aureatus* immediately following it, illustrates the method of the authors. The two descriptions are verbally identical as to the essential characters, the only difference being that *aureatus* has one less arm, and one more small plate in the third interbrachial range.

Horizon and *locality.*—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

DOLATOCRINUS CANADENSIS Whiteaves.

Dolatocrinus canadensis Whiteaves, Contr. Canad. Paleont., vol. 1, 1887, p. 99, pl. 12, figs. 3, 3*a*.—Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 315, pl. 25, figs. 7*a*, *b*.

This species, described from the Hamilton of Thedford, Ontario, was founded upon a single small specimen probably somewhat eroded. It seems to be of the type of *D. marshi*, but with 15 arms instead of 10. A form somewhat similar to *marshi* has been noted from western New York, but the material is not available for comparison.

Horizon and locality.—Hamilton shales: Thedford, Ontario.

Form 7. MAGNIFICUS group.

Calyx large to medium size, occasionally small; oblate hemispheroidal, or depressed bursiform, constricted below the arms; base broadly truncate, flat, or shallow concave. Plates highly ornamented with ridges, striae, nodes, or pustules; radial series bearing nodes round or elongate, either separated, or connected by a narrow neck, or meeting at the sutures to form a continuous median ridge:

interbrachial plates marked by rows or clusters of pustules or wrinkles more or less radiately arranged, or by radiating striae crossing the sutures to adjoining plates and tending to form geometrical figures, which when the striae are fine may become intricate and form several included triangles; more or less prominent central nodes may be formed by coalescence of these radiate structures, or nodes may be wanting. Tegmen more or less lobed, ventricose or low convex, with plates smooth, granular, rugose, bearing small spinous tubercles, or rarely strong spines. Pinnule openings few and inconspicuous, often obscured by the rugose sculpture. Arms 15 to 20, exceptionally more or fewer.

The above description applies to the leading form of this genus in the Louisville area, for which no less than 22 species and 2 varieties have been named, 15 of the species by Miller and Gurley, and 7 species with 2 varieties by other authors. The wide bursiform calyx, constricted above and truncate below, with strong pustulose or striate ornamentation, imparts a facies which would well characterize a strong and variable species. It is represented by numerous individuals, among which may be found more or less difference in superficial characters, producing just such an assemblage of minor variations as is to be expected in a dominant species, flourishing abundantly under favorable conditions, at the acme of the group to which it belongs and on the eve of its extinction.

The instability of characters in this form is evidenced by the frequent occurrence of unsymmetrical conditions among the plates of the calyx: those of the radial series are often larger or smaller in one or two rays than in the others, as seen in Miller and Gurley's figure of *D. greenei*;[16] or the interrays may be unequal, the posterior one frequently the largest; and all the principal plates—basals, radials, and interbrachials—are subject to considerable irregularities in size as between specimens otherwise identical. This unequal growth of plates which are usually pentamerously symmetrical in the crinoids produces a certain asymmetry in the contour rather frequently observed among the specimens of this form, by which the calyx will be higher or more ventricose in one part than another. Suppression of an entire ray occasionally occurs, as shown by Rowley's figure in Greene (pl. 47, fig. 2), and by specimens in my collection; also of one primibrach, as in Greene (pl. 57, figs. 16, 17, 18).

The numerous species which have been described under this form depend for the most part upon minor differences which are to be found in any vigorous and prolific species, notably those in the number and grouping of arms, upon which most of Miller and Gurley's

[16] Bull. 4, pl. 31, fig. 10; also herein, pl. 14, fig. 7.

species are founded. The testing of the value of such characters in practice emphasizes the importance of ample material. I have before me the types of 15 of Miller and Gurley's species, and in addition 31 duplicates in the Gurley collection, and 76 good specimens of my own of which 62 show the full number of arms, thus making a total of 108 specimens of this form from which the number of arms can be tabulated, to which may be added the 9 types of Rowley. These range from 10 arms to 22, distributed as follows: With 10 arms, 2; with 11 arms, 1; with 13 arms, 2; with 14 arms, 4; with 15 arms, 9; with 16 arms, 21; with 17 arms, 16; with 18 arms, 25; with 19 arms, 16; with 20 arms, 18; with 21 arms, 1; with 22 arms, 2.

While this shows a wide range of disturbance in the arm development, it will be seen that the variation is chiefly within definite limits, about 90 per cent of the specimens having from 15 to 20 arms, and 50 per cent are within one or two of the higher number; so that normally this form has either three or four arms to the ray, the differences being due to the addition or failure of an arm irregularly in one or more rays.

These various numbers do not correlate with any other character; and with the actual specimens in hand every attempt to arrange species with reference to them is soon seen to be futile. The few groups which I have tried to define according to other criteria all embrace more or less of these variations in number of arms. As is to be expected, these groups shade into one another in a most perplexing way; they are the outcome of frequent shiftings of specimens from one to another, without achieving any result that seems to proclaim their identity by any positive or well-defined and palpable character. This lack of reliable definition shows the small taxonomic value of the variations noted, and it is probable that a far more drastic cutting down of species, even to the extent of throwing them all into one, would be the more logical course. In view of the considerable reduction of species which I have felt obliged to make, and in order to avoid too much dependence upon my unsupported judgment, I am publishing herewith new and accurate drawings made from a photographic basis of nearly all of Miller and Gurley's types, arranged in juxtaposition, so that the reader may judge for himself (pls. 13, 14, and 15). These type specimens are in some cases not so clear in point of distinctness of characters as could now be selected for illustration; but I have not undertaken to prepare other figures, beyond one or two to give a better view of the general type, to illustrate variations, and to show that the purse-like contour which is the striking character of this form is not due to age, since it appears as distinctly in the smaller specimens as in the most mature (pl. 16).

DOLATOCRINUS MAGNIFICUS Miller and Gurley.

Dolatocrinus magnificus Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 1, pl. 1, figs. 1–3.

This was Miller and Gurley's first species of this form, and while its pustulose and wrinkled sculpturing is simulated to some extent in later species, this one may well stand apart on the ground of its size, coarse ornament, and massive form. The type is about 35 mm. high and 65 mm. wide. There are among my material several specimens more or less imperfect, all of approximately the same dimensions, and there is a very distinct gap in size between these and specimens of what is regarded as the next largest species—*corporosus*. The two forms are quite similar, but *magnificus*, by reason of some flattening of the interrays, takes on a somewhat pentagonal outline which other species do not possess. Half of these large specimens have 18 to 21 arms, while 90 per cent of the others have 15 arms or more, and of these, 50 per cent have 20, 21, and 22. The extra arms in these and in the type are clearly abnormal.

Horizon and locality.—Hamilton (Sellersburg) limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS CORPOROSUS Miller and Gurley.

Plate 14, figs. 1, 2; plate 16, figs 1, 2.

Dolatocrinus corporosus Miller and Gurley, Bull. 6, Ill. St. Mus., 1895, p. 50, pl. 5, figs. 1–3.—Rowley in Greene, 1903, p. 157, pl. 47, figs. 1–3.

Dolatocrinus welleri Rowley in Greene, 1903, p. 143, pl. 41, fig. 14.

Dolatocrinus corporosus, var. *decoratus* Rowley, 1903, p. 149, pl. 43, figs. 7–9.

I have 12 specimens, besides two in the Gurley collection, which may fairly be assigned to this species, with its wide calyx, low tegmen, and coarse wrinkled ornamentation. It is typically a large species, ranging from 25 to 30 mm. height of calyx and 45 to 50 (exceptionally 75) mm. width, and it is approximately 20-armed. There are specimens with 16, 17, 18, 19, and 20 arms, and also exceptionally one with 10. Omitting the last, and counting the types, 50 per cent of the specimens have full 20 arms. I figure on plate 16 a maximum flattened specimen of this or one of the closely allied species, and also one which is a fine example of the typical bursiform calyx, but is a variant with only 10 arms.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

DOLATOCRINUS INDIANENSIS Miller and Gurley.

Plate 14, figs. 3–6.

Dolatocrinus indianensis Miller and Gurley, Bull. 8, Ill. St. Mus., 1896, p. 40, pl. 3, figs. 1–3.

Dolatocrinus preciosus Miller and Gurley, Bull. 9, 1896, p. 40, pl. 2, figs. 27–29.—Rowley in Greene, 1903, p. 152, pl. 45, figs. 1–3, 4–6.

Both the type specimens to which the above names have been given are poorly preserved, and do not show the surface characters

very well. They are good examples of the bursiform calyx. But for the lower and smoother tegmen, which may both be incidental to fossilization, they could not be distinguished from the form included under *lineolatus*. A form strongly resembling these occurs in the Hamilton of Thedford, Ontario.

Horizon and locality.—Hamilton (Sellersburg), limestone: Clarkstown, Indiana, and vicinity.

DOLATOCRINUS GREENEI Miller and Gurley.

Plate 14, figs. 7–9; plate 16, fig. 3.

Dolatocrinus greenei Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 28, pl. 3, figs. 10–12.—Rowley in Greene, 1903, p. 158, pl. 47, figs. 4–6. 25.

Dolatocrinus corporosus, var. *concinnus* Rowley in Greene, 1903, p. 148, pl. 44, figs. 4–6.

The more distinct radiating striae furnishes the slight ground for separating this from the *corporosus* form, and the distinction becomes decidedly hazy when the intermediate *indianensis* form is brought into connection with the others. All the specimens are large, with flattened tegmen, and the tendency is toward the maximum number of arms. The type of *greenei* is abnormal in having two rays larger than the others. Rowley's specimen is perhaps the most characteristic. Of five specimens in the Gurley collection labeled *greenei*, two have the specified number of 19 arms, two 18, and one 16; the last three labeled "small specimens," apparently by Mr. Miller himself.

Horizon and locality.—Hamilton (Sellersburg), limestone: Louisville, Kentucky, and vicinity.

DOLATOCRINUS LINEOLATUS Miller and Gurley.

Plate 13, figs. 13–18; plate 14, figs. 10, 11; plate 15, fig. 7; plate 16, fig. 8.

Dolatocrinus lineolatus Miller and Gurley, Bull. 4, Ill. St. Mus., 1894, p. 27, pl. 3, figs. 7–9.

Dolatocrinus sacculus Miller and Gurley, Bull. 7, Ill. St. Mus., 1896, p. 58, pl. 3, figs. 11, 12.

Dolatocrinus salebrosus Miller and Gurley, Bull. 7, p. 59, pl. 3, figs. 13–15.

Dolatocrinus charlestownensis Miller and Gurley, Bull. 8, 1896, p. 44, pl. 3, figs. 10–12.—Rowley in Greene, 1903, p. 153, pl. 45, figs. 7–9.

Dolatocrinus cistula Miller and Gurley, Bull. 9, 1896, p. 46, pl. 3, figs. 1–3.

Dolatocrinus asper Miller and Gurley, Bull. 9, 1896, p. 47, pl. 3, figs. 10–12.

Dolatocrinus eicosidactylus Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 319, pl. 26, figs. 5*a–d*.

Dolatocrinus springeri Rowley in Greene, 1903, p. 136, pl. 39. figs. 9–11.

The type included under the above name is the most abundant form in the present group. There are about 30 specimens in the collection which probably belong together, ranging in size from 15 to 35 mm. in height and 20 to 50 mm. in width. In 20 of these the arms can be counted, and about 75 per cent of them have from

15 to 18 arms; three have less than 15; one only 10; and the remainder have more, up to 20 and one abnormal 22; so this may be considered as typically a 15-armed form, as distinguished from the approximately 20 arms of *corporosus*. The generally higher and narrower calyx as compared with that of the *corporosus* type, and the more ventricose tegmen, with smoother plates rather obscurely defined and tending to develop small spinous nodes, are the characters to be noted. None of the Miller and Gurley types are good representatives of the mature stage of this form, and I have given a figure of the type of Wachsmuth and Springer's *D. eicosidactylus* which is much more characteristic; it attains even a larger size than this. I also figure a 10-armed specimen which belongs either here or under *D. bellulus*, as one chooses (pl. 16, fig. 5). Minimum stages of both species are shown by plate 16, figures 7, 8.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

DOLATOCRINUS BELLULUS Miller and Gurley.

Plate 15, figs. 1–6; plate 16, figs. 4–7 (?9).

Dolatocrinus bellulus Miller and Gurley, Bull. 6, 1895, p. 57, pl. 5, figs. 16–18.
Dolatocrinus basilicus Miller and Gurley, Bull. 9, 1896, p. 43, pl. 3, figs. 1–3.
Dolatocrinus noduliferus Rowley in Greene, 1903, p. 140, pl. 41, figs. 1–3.

This and the next form are distinguished from those preceding by reason of having prominent nodes and discontinuous median ridges along the radial series, while they differ from each other mainly by the ventricose, lobed tegmen with small spinous tubercles in this species, as opposed to the low, non-spiniferous tegmen of the next following.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

DOLATOCRINUS NODOSUS Miller and Gurley.

Plate 15, figs. 9–11.

Dolatocrinus nodosus Miller and Gurley, Bull. 7, Ill. St. Mus., 1895, p. 56, pl. 3, figs. 1–3.—Rowley in Greene, 1903, p. 163, pl. 48, figs. 1–3.
Dolatocrinus tuberculatus Wachsmuth and Springer, N. A. Crin. Cam., 1897, p. 324, pl. 25, fig. 3.
Dolatocrinus multinodosus Rowley in Greene, 1903, p. 147, pl. 44, figs. 1–3.
Dolatocrinus elegantulus Rowley in Greene, 1903, p. 150, pl. 44, figs. 10–12.

Like the last, except for the flat tegmen, without nodes or spines, but sometimes with very small pustules, which may occur on any tegmen classed as smooth.

Horizon and locality.—Hamilton (Sellersburg) limestone: Charlestown, Indiana, and vicinity.

DOLATOCRINUS FUNGIFERUS Rowley.

Plate 15, figs. 12, 13.

Dolatocrinus fungiferus ROWLEY in Greene, Contr. Indiana Paleontology, 1903, p. 134, pl. 39, figs. 1–3.

Of the type of *D. nodosus*, but distinguished from that species and all others of the genus by having the tegmen studded with short, thick, mushroom-shaped spines, which project like nail heads. It is a thoroughly well-marked species, not depending upon the evidence of a single type, for I have seven specimens in which the peculiar spines and correlated characters are constant; but the number of arms varies from 17 to 19. Rowley's figures give a very good picture of the species. The description gives the horizon as "Middle Devonian," which was Rowley's term for the Onondaga beds at Louisville, while he called the Hamilton "Upper Devonian." This was an oversight by Mr. Greene, as this form is typically Hamilton, and all my specimens, most of which were collected by him, are from above the hydraulic beds.

Horizon and locality.—Hamilton (Sellersburg) limestone: Louisville, Kentucky, and vicinity.

The final result of our review of the species and varieties of *Dolatocrinus* heretofore described, with the few new species added, may be shown by the following summary:

Species and varieties of Dolatocrinus.

	Described before.	Synonyms.	Recognized.	New.	Total. valid.
Hamilton	62	40	22	1	23
Onondaga	15	6	9	3	12
Total.	77	46	31	4	35

EXPLANATION OF PLATES.

Enlargement, if any, of the figures is indicated by the fraction at the end of the paragraph. Unless so noted, the figure is of natural size. All specimens figured, except as otherwise stated, are in the author's collection, now in the United States National Museum. No effort has been made to orient the specimens in the usual way with reference to the posterior side, which can not always be identified; they are posed rather with reference to the light in photographing.